THE WESTERN AUSTRALIAN NATURALIST

Vol. 29 No. 2 October 30, 2013

Scattered Marble Gum over Triodia hummock grassland on Yamarna Station in the Great Victoria Desert, November 2005. Photo: Mark Cowan

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Print Post Approved
PP 6358 23/00015
ISSN 0726 9609

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ABN 97 932 293 116

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THE WESTERN AUSTRALIAN
NATURALIST

Vol. 29 30th October 2013 No. 2

NOTES ON THE ECOLOGY AND NATURAL HISTORY OF TWO UNCOMMON ARBOREAL AGAMID LIZARDS *DIPORIPHORA PARACONVERGENS* AND *LOPHOGNATHUS LONGIROSTRIS* IN THE GREAT VICTORIA DESERT OF WESTERN AUSTRALIA

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ABSTRACT

Ecological data on *Diporiphora paraconvergens* and *Lophognathus longirostris* are presented. Both species are arboreal, with long tails used as counterbalances during climbing. Both species are associated with sandridges. *Diporiphora* and juvenile *Lophognathus* live in large shrubs, whereas adult *Lophognathus* are often found higher up in Marble Gum trees well above ground. Both species frequently forage on the ground. Both are active thermoregulators. Ambient air temperatures average about 25°C and active body temperatures average 33–34°C in both species, and average time of activity is during midday around noon. These lizards are generalized predators that consume a wide range of insects, especially wasps, hemiptera, beetles, ants, mantids and phasmids as well as larvae of various insects. *Diporiphora* is partially herbivorous and eats both leaves and flowers. *Lophognathus* consumes katydids and grasshoppers. Both dietary and microhabitat niche breadths are greater than those of many other sympatric lizard species. Mating occurs and eggs are laid during the Austral Spring. Average clutch size is 3 eggs in *Diporiphora* and 4.4 in *Lophognathus*. Relative clutch mass of 4 gravid female *Lophognathus* with eggs in their oviducts is 0.151.

INTRODUCTION

The agamid genus *Diporiphora* has undergone recent revision (Doughty *et al.* 2012) with description of a new species *Diporiphora paraconvergens*. During the Austral Springs and Summers of 1966–68, I encountered *Diporiphora paraconvergens* and *Lophognathus longirostris* on two sandridge study sites, the D-area (34 km W. Lorna Glen HS, 26° 14' S. x 121° 13' E.) and the E-area (8 km NE Dunges Table Hill, 28° 08' S. x 123° 55' E.), both in the Great Victoria Desert. In many years of subsequent field work at other sites, I never found any more *Diporiphora* but did collect some *Lophognathus* at my long-term Redsands study site (10 km WSW Yamarna, 28° 12' S. x 123° 35' E.), although they were never very abundant. Two juvenile *Lophognathus*, probably not residents but rather dispersers, were pit-trapped 4 km south of Redsands on my B-area (28° 13.5' S. x 123° 55' E.). I consider these propagules evidence of metapopulation structure. Similarly, *Diporiphora* were locally extinct at the Redsands study site where suitable habitat and microhabitats occur.

The Great Victoria Desert of Australia is predominantly sandy with red sands, and supports a vegetation consisting mainly of so-called "spinifex" or "porcupine" grasses (genus *Triodia*) plus various species of gum trees (*Eucalyptus*), especially Marble Gums (*Eucalyptus gonglyocarpa*). Marble Gum trees are the favored habitat of adult *Lophognathus*. Shrubs including *Eremophila*,

Figure 1. *Diporiphora paraconvergens* in typical alert posture in a shrub.

Figure 2. *Lophognathus longirostris* poised in a small desert tree (note its very long tail).

Grevillea, *Hakea*, and *Thryptomene* also occur and are used by juvenile lizards of both species. Stabilized long red sandridges, parallel to prevailing winds are scattered throughout the Great Victoria Desert, particularly in the eastern interior. Extensive areas of flat sandplain occur as well. The region is very heterogeneous with mixed ecotonal habitats of shrubs, *Triodia*, *Acacia*, and *Eucalyptus* on desert loams. Beard (1974) and Shephard (1995) describe and illustrate the vegetation of the region. The climate is an arid continental regime, with cool usually dry winters and warm springs and autumns but quite hot summers. Most precipitation falls during summer thunderstorms. Wildfires are frequently set by lightning and vegetation biomass and cover vary through time as plants undergo secondary sucession following fire (Pianka 1996; Pianka and Goodyear 2012).

METHODS

My assistants and I observed and collected 37 *Diporiphora paraconvergens* at 2 study areas and 93 *Lophognathus longirostris* at 4 study sites. These data were augmented with limited observations on a few other lizards that were not collected. We recorded air and body temperatures, times of activity, microhabitat, fresh

snout-vent length (SVL), tail length, and weight for as many lizards as possible. Stomach contents were identified and prey volumes estimated for all lizards collected. Reproductive condition was also recorded: for males, lengths of testes were measured; for females, egg sizes were measured and numbers were counted, and whether eggs were ovarian or oviductal was noted [some of these data were summarized in appendices in Pianka (1986)]. Niche breadths were calculated using the inverse of Simpson's (1949) index of diversity [$D = 1/ \Sigma p_i^2$] where p_i is the proportion of resource state *i*.

RESULTS

Habitat

Both species are habitat specialists, and seem to prefer slopes and crests of sandridges, although *Lophognathus* has a broader habitat niche breadth and is more frequently found at the base of sandridges or out on flat sandplains away from sandridges (Table 1).

Table 1. Numbers and percentages of lizards found in different sandridge habitat zones. Sample sizes (N) and habitat niche breadths (HNB) are given at bottom of the table. Lizards at an interface between habitats split in half.

Habitat	*Diporiphora*		*Lophognathus*	
	N	%	N	%
Flat	0.5	1.3	11	11.8
Base	1.5	3.9	12	12.9
Slope	8	21.1	13	13.9
Crest	28	73.7	57	61.3
Sample (N)	**38**		**93**	
HNB.	**1.698**		**2.348**	

Anatomy

Diporiphora is smaller (mean SVL = 45.6 mm, adults = 50.4 mm) than *Lophognathus* (mean SVL = 67 mm, adults = 100.3 mm). Female *Lophognathus* reach sexual maturity at about 94 mm SVL. No sexual size dimorphism is evident in *Lophognathus*, but adult female *Diporiphora* are larger than adult males (56.5 mm versus 47.9 mm).

Diporiphora and *Lophognathus* are arboreal, with very long tails used as counterbalances during climbing. They may climb to increase their visual field as well as to avoid high surface temperatures during the heat of the day in summer.

Microhabitat

Both species are usually associated with large bushes (Table 2). In both species, over 30 % of lizards were above ground when first sighted. *Lophognathus* also frequents trees and they are more often found higher up than *Diporiphora*.

Thermoregulation

Both species are active thermoregulators. Body temperatures of 32 active *Diporiphora* ranged from 26.3 to 41°C averaging 33.7°C with a standard deviation of 3.31 (average air temperature was 25.1°C with a standard deviation

Table 2. Percentages of lizards encountered in 14 different microhabitats. Microhabitat niche breadths (MHNB) is given at the bottom of the table.

Micro-habitat	*Diporiphora*	*Lophognathus*
Open Sun	5.7	6.96
Grass Sun	10	3.91
Bush Sun	38.6	31.30
Tree Sun		2.17
Other Sun	1.4	0.87
Open Shade		2.61
Grass Shade	1.4	2.17
Bush Shade	10	7.83
Tree Shade		5.65
Other Shade	1.4	0.87
Low Sun	17.1	10.87
Low Shade	8.6	6.52
High Sun	5.7	9.13
High Shade		9.13
Sample (N)	35	115
MHNB	4.7	6.75

of 6.12). Body temperatures of 76 active *Lophognathus* ranged from 24.8 to 45.4°C, averaging 34.3°C with a standard deviation of 3.84 (average air temperature was 25.6°C with a standard deviation of 6.26). Body temperature is correlated with air temperature (Fig. 3 and Fig. 4).

These lizards bask when it is cold, and seek shade when it is warm. During the heat of mid-day, they sometimes climb up above ground and face directly into the sun, thereby positioning themselves in cooler air and reducing heat load. Climbing also increases the area of their visual field and may help them avoid contact with potential predators.

Diets

Diporiphora and *Lophognathus* are sit-and-wait ambush predators with fairly broad diets. They are omnivorous, eating both plant and animal foods (Table 3). The most important insect prey item eaten by both species is wasps (29% and 20.7%). Both species also prey on hemipterans (11.2% and 13.3% of diets by volume), beetles (9.8% and 7.2% of diets by volume), as well as larvae of various insects (8.7% and 9.6% of diets by volume). Other less important prey items include ants, mantids and phasmids. *Diporiphora* are omnivorous con-

Table 3. Percentages of various dietary items by volume along with total volume and dietary niche breadths.

Prey Category	*Diporiphora*	*Lophognathus*
Centipedes	0	0.634
Spiders	3.1873	0.9863
Ants	7.1713	7.2913
Wasps	20.7171	29.13
Locustids	2.3904	10.391
Roaches	0	0.7045
Mantids/ Phasmids	5.1793	5.3892
Beetles	7.1713	9.7922
Termites	0	2.1134
Hemiptera	11.1554	13.3145
Diptera	1.1952	2.6418
Larvae	9.5618	8.7355
Other Insects	3.1873	5.7062
Vegetation	29.0837	1.6555
Other	0	0.0704
UnID	0	1.4442
Total Volume	2.51	28.39
Dietary Niche Breadth	**6.07**	**6.95**

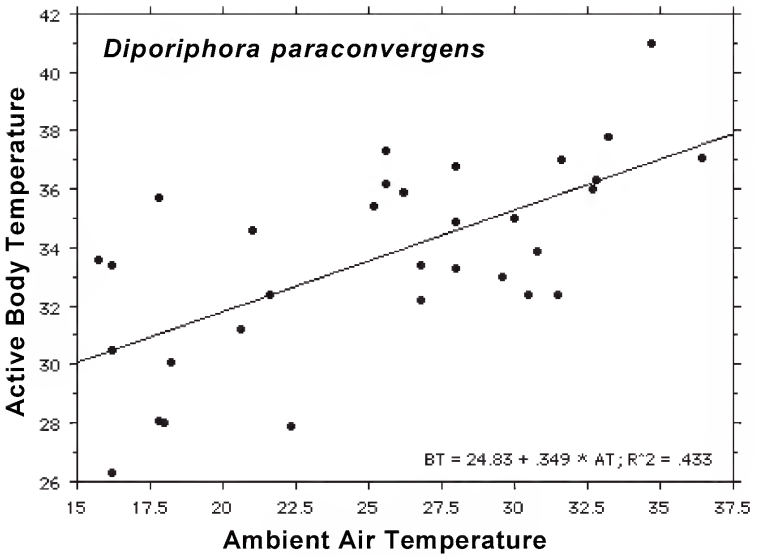

Figure 3. Body temperatures plotted against ambient air temperature for 32 active *Diporiphora*.

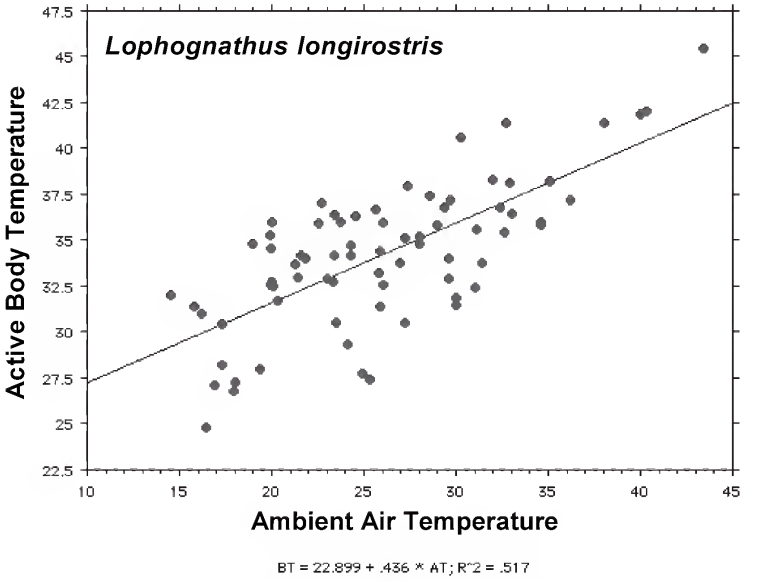

Figure 4. Body temperatures plotted against ambient air temperature for 76 active *Lophognathus longirostris*.

suming many plant materials, both leaves and flower heads, which constitute about 29% of their diet by volume. Katydids and grasshoppers constitute 10.4% of the *Lophognathus* diet by volume.

Both dietary and microhabitat niche breadths are greater than those of many other sympatric lizard species (Pianka 2014).

Reproduction

15 adult male *Diporiphora* averaged 47.9 mm in SVL and 9 adult male *Lophognathus* with enlarged testes found in November and December averaged 101.6 mm in SVL. Average adult female SVL is 56.5 mm in *Diporiphora* and 99 mm in *Lophognathus*. Clutch sizes of 6 female *Diporiphora* averaged 3. Gravid female *Diporiphora* were found in September, November and early December. One gravid female *Diporiphora* was found in January, suggesting that some females could lay a second clutch. Gravid female *Lophognathus* contained from 3 to 6 eggs (mean 4.44) and were found in October, November and December. Relative clutch mass in *Lophognathus* is 0.151. Hatchlings are small (SVL 30–33 mm in *Diporiphora* and 40–44 mm in *Lophognathus*). Juveniles appear to grow fast and undoubtedly suffer fairly heavy mortality. These lizards are not social and I have never observed courtship or mating.

Predation

Predators on *Diporiphora* and *Lophognathus* would include various species of birds of prey especially Brown Falcons and Australian Kestrels, bustards, large snakes, and monitor lizards *Varanus eremius*, *V. tristis* and *V. gouldii* as well as introduced cats and foxes. Both *Diporiphora* and *Lophognathus* rely heavily on camouflage to avoid predators, typically freezing and holding very still until the threat goes away. However, if pursued, of course they run rapidly away from an attacker. *Lophognathus* can run bipedally on their hind legs with tails held high as counterbalances.

DISCUSSION

Dietary and microhabitat niche breadths are greater in both *Diporiphora paraconvergens* and *Lophognathus longirostris* than in many other sympatric lizard species. However, because both species are habitat specialists being restricted to sites with sandridges and are never very abundant, these two arboreal species were categorized as rare by Pianka (2014). Both species exhibit features suggestive of metapopulation structure, such as dispersal propagules, local extinctions, and/or being absent from sites with suitable habitats and microhabitats (see Table 4 in Pianka (2014)).

ACKNOWLEDGEMENTS

H. L. Dunlap assisted with field work. M. E. Egan and T. D.

Schultz helped identify stomach contents. My research has been supported out of my own pocket and by grants from the National Geographic Society, the John Simon Guggenheim Memorial Foundation, a senior Fulbright Research Scholarship, the Australian-American Educational Foundation, the University Research Institute of the Graduate School at The University of Texas at Austin, the Denton A. Cooley Centennial Professorship in Zoology at The University of Texas at Austin, the U. S. National Science Foundation, and the U. S. National Aeronautics and Space Administration. I thank the staffs of the Department of Zoology at the University of Western Australia, the Western Australian Museum, and the Western Australian Department of Parks and Wildlife (previously Department of Conservation and Land Management (CALM)). Lizards were collected under permits issued by CALM and with the approval of appropriate animal ethics committees in Australia and the University of Texas.

REFERENCES

BEARD, J. S. 1974. *Great Victoria Desert. The vegetation of the Great Victoria desert area.* (With maps.) Vegetation Survey of Western Australia, Nedlands.

DOUGHTY, P., L. KEALLEY, and J. MELVILLE. 2012. Taxonomic assessment of *Diporiphora* (Reptilia, Agamidae) dragon lizards from the western arid zone of Australia. *Zoo Taxa* 3518: 1–24.

PIANKA, E. R. 1986. *Ecology and Natural History of Desert Lizards. Analyses of the Ecological Niche and Community Structure.* Princeton University Press, Princeton, New Jersey.

PIANKA, E. R. 1996. Long-term changes in Lizard Assemblages in the Great Victoria Desert: Dynamic Habitat Mosaics in Response to Wildfires. Chapter 8 (pp. 191–215) in M. L. Cody and J. A. Smallwood (eds.) *Long-term studies of vertebrate communities.* Academic Press.

PIANKA, E. R. 2014. Rarity in Australian desert lizards. *Austral Ecology* 39, in press.

PIANKA, E. R. and S. E. GOODYEAR. 2012. Lizard responses to wildfire in arid interior Australia: Long-term experimental data and commonalities with other studies. *Austral Ecology* 37: 1–11.

SHEPHARD, M. 1995. *The Great Victoria Desert.* Reed Books, Chatswood, NSW.

SIMPSON, E. H. 1949. Measurement of diversity. *Nature* 163, 688.

NOTES ON THE ECOLOGY AND NATURAL HISTORY OF TWO UNCOMMON TERRESTRIAL AGAMID LIZARDS *CTENOPHORUS CLAYI* AND *C. FORDI* IN THE GREAT VICTORIA DESERT OF WESTERN AUSTRALIA

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ABSTRACT

Ecological data on *Ctenophorus clayi* and *Ctenophorus fordi* are presented. *Ctenophorus clayi* is a habitat generalist found on sites close to sandridges, whereas *Ctenophorus fordi* is a terrestrial habitat specialist, typically found only on sites with sandridges with which it is closely associated, (habitat niche breadths = 3.7 and 2.13, respectively). Individuals are usually found either near spinifex tussocks or bushes or in the open. Microhabitat niche breadths are 4.1 and 2.99, respectively.

These lizards are active thermoregulators: Ambient air temperatures for *C. clayi* average 29.6°C and active body temperatures average 36.9°C. Ambient air temperatures for *C. fordi* average about 26.3°C and active body temperatures average 37.2°C. Average time of activity is during midday around 1100–1200 hrs.

Grasshoppers are the most important prey of *C. clayi* (30.5% by volume) which also consume termites (9.6%) and ants (9.5%) as well as hemipterans (7.6% by volume). Ants are the most important prey of *C. fordi* (45.7% by volume) which also consume hemipterans (14.0% by volume) and wasps (11.8% by volume) as well as smaller quantities of other insects. *C. clayi* has a broader dietary niche breadth than *C. fordi* which is an ant specialist. Dietary niche breadths are 6.35 and 3.96, respectively.

In both species, mating occurs during the Austral Spring, when eggs are laid. Clutch size in *C. clayi* varies from 1 to 4 and averages 2.77 eggs (N = 27). Clutch size in *C. fordi* is usually 2 eggs (mean = 2.3, N = 13). Relative clutch mass (RCM) of 24 gravid female *C. clayi* with oviductal eggs is 19.9% whereas RCM of one gravid female *C. fordi* with 2 eggs in her oviducts is 4.4%.

Aspects of the ecologies of these two terrestrial species are compared. Both *Ctenophorus clayi* and *C. fordi* are

uncommon and both are found only on study sites located near sandridges, but *C. clayi* has a much broader habitat niche as compared to *C. fordi*. Like two other arboreal sandridge agamid species *Diporiphora* and *Lophognathus* (Pianka 2013), both these terrestrial species exhibit features suggestive of metapopulation structure, such as dispersal propagules and/or being absent from sites with suitable habitats and microhabitats.

INTRODUCTION

During Austral springs and summers of 1966–68, I encountered only one *Ctenophorus clayi* at a sandridge study site, the E-area (8 km NE Dunges Table Hill, 28° 08' S. x 123° 55' E.) in the Great Victoria Desert. In subsequent years, *C. clayi* was much more abundant at two other long-term nearby study sites (Redsands: 10 km WSW Yamarna, 28° 12' S. x 123° 35' E., and 4 km South of Redsands on the B-area: 140 km East of Laverton, 28° 13' 30" S. x 123° 35' 30" E.).

Figure 1. Adult *Ctenophorus clayi*.

During the same time period, the Austral Springs and summers of 1966–68, I encountered a population of *Ctenophorus fordi* at the same sandridge study site, the E-area (8 km NE Dunges Table Hill, 28° 08' S. x 123° 55' E.) in the Great Victoria Desert. In many years of subsequent field work at other sites, I never found any more populations of *C. fordi* but I did collect one lone adult gravid female at my sandplain G-area (27 km S Neale Junction, 28° 30' x 125° 50') and one lone male at my long-term Redsands study site (10 km WSW Yamarna, 28° 12' S. x

Figure 2. Adult female *Ctenophorus fordi*.

123° 35' E.). The G-area female can be considered a reproductive dispersal propagule, far away from sandridges making this species an example of a metapopulation. Similarly, I witnessed extinction of the last lone male at Redsands (this individual could also be considered a failed dispersal propagule).

Neither species was encountered in apparently suitable sandridge habitats during extensive pit trapping from 2003 to 2006 at Lorna Glen, about 300+ km to the NW (Mark Cowan, pers. comm.).

Merely being in an alien habitat is not necessarily a death sentence, as these habitats offer shelter and food — a migrant that succeeds in reaching its correct habitat could also reap the benefits of sweepstakes reproductive success.

The Great Victoria Desert of Australia is predominantly sandy with red sands, and supports a vegetation consisting mainly of so-called "spinifex" or "porcupine" grasses (genus *Triodia*) plus various species of gum trees (*Eucalyptus*), especially Marble Gums (*Eucalyptus gonglyocarpa*) and various shrubs including *Eremophila*, *Grevillea*, *Hakea*, and *Thryptomene*. Stabilized long red sandridges, parallel to prevailing winds are scattered throughout the Great Victoria Desert, particularly in the eastern interior. Extensive areas of flat sandplain occur as well. The region is very heterogeneous with mixed ecotonal habitats of shrubs, *Triodia*, *Acacia*, and *Eucalyptus* on desert loams. Beard (1974) and Shephard (1995) describe and illustrate the vegetation of the region. The climate is an arid continental regime, with cool usually dry winters and warm springs and autumns but quite hot summers. Most precipitation falls during summer thunderstorms. Wildfires are frequently set by lightning and vegetation biomass and cover vary through time as plants undergo secondary sucession following fire (Pianka 1996; Pianka and Goodyear 2012).

METHODS

My assistants and I observed and collected 293 *Ctenophorus clayi* at 3 study areas and nearby incidental non-study areas between 1966 and 2008. We observed and collected 110 *Ctenophorus fordi* on the E-area plus the singletons at two other study sites described above, as well as a few lizards on nearby incidental non-study areas. We recorded air and body temperatures, times of activity, microhabitat, fresh snout-vent length (SVL), tail length, and weight for as many lizards as possible. Stomach contents were identified and prey volumes estimated for all lizards collected. Reproductive condition was also recorded: for males, lengths of testes were measured; for females, egg sizes were measured and numbers counted, and whether eggs were ovarian or oviductal was noted [some of these data were summarized in appendices

in Pianka (1986)]. Niche breadths were calculated using the inverse of Simpson's (1949) index of diversity [$D = 1/\ \Sigma p_i^2$] where p_i is the proportion of resource state *i*. Habitat niches are based on four dimensions, microhabitat niches on 15 dimensions, and dietary niches on 20 dimensions.

RESULTS

Habitat

Although *Ctenophorus clayi* is usually found on sites close to sandridges, it is a habitat generalist, with a broad habitat niche breadth. In contrast, *Ctenophorus fordi* is a habitat specialist with a much narrower habitat niche breadth, which strongly prefers slopes and crests of sandridges (Table 1).

Table 1. Numbers and percentages of lizards found in four different sandridge habitat zones. Lizards at an interface between habitats are split between shared habitats. Sample size (N), habitat niche breadths (HNB), and standardized HNBs, standardized by division by 4 are given at bottom of the table.

Habitat	*C. clayi*		*C. fordi*	
Number, %	**N**	**%**	**N**	**%**
Flat	59	27.3	1	0.9
Base	64.5	29.9	3	2.6
Slope	27.5	12.7	60	52.6
Crest	65	30.1	50	43.9
Sample (N)	**216**		**114**	
HNB	**3.7**		**2.13**	
Standardized HNB	**0.925**		**0.533**	

Microhabitat

Ctenophorus clayi is often found in the open sun, but is also associated with spinifex tussocks and less often with bushes (Table 2). Three lizards were slightly above ground when first sighted. *Ctenophorus fordi* is also a microhabitat specialist, usually found either in the open sun or associated with large bushes.

Thermoregulation

Body temperatures of 40 active *Ctenophorus clayi* ranged from 30.3 to 42.8°C averaging 36.9°C with a standard deviation of 2.67 (average air temperature was 29.6°C with a standard deviation of 4.25). Body temperature is weakly correlated with air temperature (Figure 3).

Ctenophorus fordi is also an active thermoregulator. Body temper-

Table 2. Percentages of lizards encountered in 9 different microhabitats. Microhabitat niche breadths (MHNB) are given at the bottom of the table.

	Ctenophorus clayi		*Ctenophorus fordi*	
Microhabitat	**N**	**%**	**N**	**%**
Open Sun	18.5	37	56.5	50.9
Grass Sun	14.25	28.5	4	3.6
Bush Sun	3.25	6.5	17.5	15.8
Other Sun	0	0	1	0.9
Open Shade	3.5	7	4	3.6
Grass Shade	5.25	10.5	3	2.7
Bush Shade	2.25	4.5	24	21.6
Other Shade	0	0	1	0.9
Low Sun	3	6	0	0
Sample (N)	50		111	
MHNB	**4.1**		**2.99**	

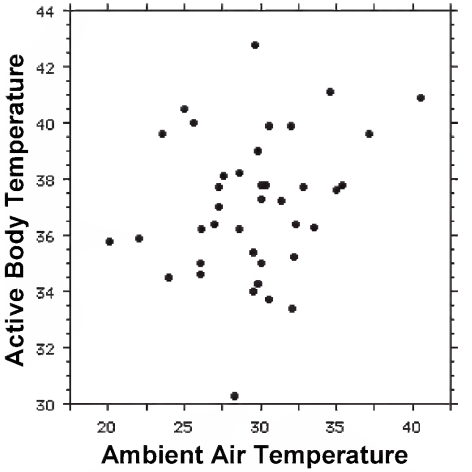

Figure 3. Body temperatures plotted against ambient air temperatures for 40 active *C. clayi.*

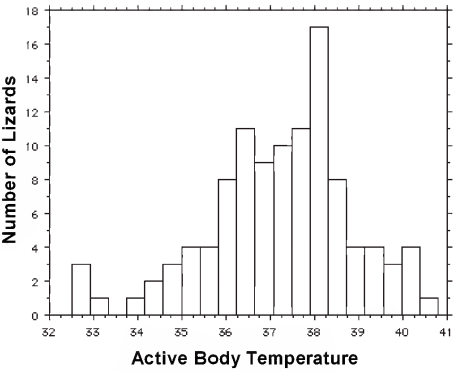

Figure 4. Histogram of active body temperatures in *C. fordi.*

atures of 108 active lizards ranged from 32.5 to 40.8°C averaging 37.2°C with a standard deviation of 1.65 (Figure 4) Average air temperature was 26.3°C with a standard deviation of 4.73. Body temperature is significantly correlated ($r = 0.52$, $P < 0.01$) with air temperature (Figure 5).

Like most heliothermic diurnal desert lizards, both of these species bask when it is cold, and seek shade or go down into burrows when it is hot. During

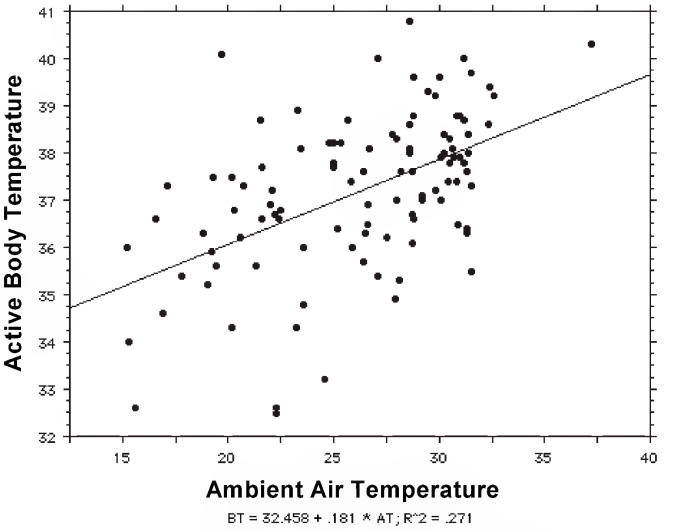

Figure 5. Active body temperatures plotted against ambient air temperature for 108 active *C. fordi.*

the heat of mid-day, *C. clayi* sometimes climb up above ground and face directly into the sun, thereby positioning themselves in cooler air and reducing heat load. Climbing also increases the area of their visual field and presumably may help them avoid contact with potential predators.

Diets

Both species are sit-and-wait ambush predators. *C. clayi* has a fairly broad diet (Dietary niche breadth = 6.35, Table 3). Grasshoppers are the most important insect prey item eaten (30.5% of diet by volume). Termites and ants constitute 9.6 and 9.5% of the diet by volume, respectively. Hemipterans, scorpions, beetles, spiders, and wasps are eaten in smaller amounts. Ants are the most important insect prey item eaten (45.7%) by *C. fordi*. Hemipterans (14.0% of diet by volume) and wasps (11.8% of diet by volume) are also eaten. Grasshoppers constitute 5.1% of the diet by volume (Table 3). Dietary niche breadth of *C. fordi* is moderate at 3.96.

Reproduction

As judged by enlarged testes in male *C. clayi* and females carrying eggs, both sexes reach maturity at about the same size, around 44–45 mm in SVL. *C. clayi* females were gravid from October through February (N=27).

Table 3. Composition of the diets of two terrestrial species of *Ctenophorus*.

	Ctenophorus clayi			*Ctenophorus fordi*		
	No.	**Vol.**	**%**	**No.**	**Vol.**	**%**
Centipedes	9	0.22	0.77	1	0.1	0.75
Spiders	61	1.19	4.20	24	0.65	4.86
Scorpions	2	2.1	7.36	2	0.01	0.07
Ants	516	2.71	9.49	2031	6.12	45.74
Wasps	44	0.96	3.36	56	1.58	11.81
Locustids	122	8.7	30.47	18	0.68	5.08
Thysanurans	54	0.59	2.07	7	0.13	0.97
Roaches	6	0.12	0.42	0	0	0.00
Mantids/ Phasmids	5	0.2	0.70	0	0	0.00
Beetles	65	2.08	7.29	37	0.38	2.84
Termites	0	2.73	9.56	2	0.02	0.15
Hemipterans	117	2.16	7.57	212	1.87	13.98
Diptera	5	0.11	0.39	8	0.27	2.02
Lepidoptera	0			4	0.26	1.94
Larvae	29	1.07	3.75	4	0.35	2.62
Other Insects	12	0.53	1.86	27	0.71	5.31
Vegetation	13	0.39	1.37	13	0.25	1.87
Other Unidentified	91	2.68	9.39	3	0	0
Totals	**1151**	**28.54**	**100.0**	**2445**	**13.38**	**100**
Dietary N. B.			**6.35**			**3.96**

Average clutch size is 2.77. Relative clutch mass (clutch weight as a percentage of female body weight) is 19.9%. *C. clayi* hatchlings are small (SVL 23–27 mm). Juveniles grow fast and probably suffer fairly heavy mortality.

30 adult male *C. fordi* with enlarged testes found from September to December averaged 50.7 mm in SVL. Average adult *C. fordi* female SVL is 51.3 mm. Clutch sizes of 13 female *C. fordi* were either 2 or 3 and averaged 2.3. Gravid females were found in September, October, November and early December. One gravid female *C. fordi* found in October contained 2 shelled eggs in her oviducts. Relative clutch mass of this one female *C. fordi* is 4.4%. Hatchlings emerge in early December and are small (SVL 25 mm).

Juvenile *C. fordi* grow fast and undoubtedly suffer fairly heavy mortality.

Predation

Predators on both *C. clayi* and *C. fordi* include various species of birds of prey especially Brown Falcons and Australian Kestrels, bustards, large snakes, and the monitor lizards *Varanus eremius*, *Varanus tristis* and *Varanus gouldii* as well as introduced cats and foxes. Both species rely heavily on camouflage to avoid predators, typically freezing and holding very still until the threat goes away. However, if pursued, they run rapidly away from an attacker or dart down a burrow.

DISCUSSION

Comparisons

Both *Ctenophorus clayi* and *C. fordi* are uncommon and limited to only a few study sites with sandridges located nearby. However, whereas *C. clayi* is a habitat generalist found out on flats, base, slopes, and crests of sandridges, *C. fordi* is a specialist, closely restricted to slopes and crests of sandridges where 96.5% of lizards were found (two lone isolated individual *C. fordi* were found on areas G and R). *C. clayi* has a much broader habitat niche (3.7) as compared to *C. fordi* (only 2.13). Like two other arboreal sandridge agamid species *Diporiphora* and *Lophognathus* (Pianka 2013), both species exhibit features suggestive of metapopulation structure (Levins

Table 4. Presence/absence and sample sizes of 4 agamid species on 5 study sites.

Species	D Sandridges	E Sandridges	G Sandplain	R Sandridges	B Sandplain (ridges nearby)
Diporiphora	18	17			
Lophognathus	29	11		40	2 juveniles
C. clayi		1 juvenile		234	45
C.fordi		105	1 gravid ♀	1 adult ♂	

1969; Harrison et al. 1988), such as dispersal propagules, local extinctions, and/or being absent from sites with suitable habitats and microhabitats (Table 4).

Their use of microhabitats differs with 39% *C. clayi* found in spinifex sun or shade as compared to only 6.3% of *C. fordi*, which species is more often associated with sun or shade in the open or near bushes 88.3% as compared to only 55% in *C. clayi*. *C. clayi* has a broader microhabitat niche breadth (4.1) than *C. fordi* (2.99). Major prey of *C. clayi* is grasshoppers (30.5%), which constitute only 5.1% of the diet by volume in *C. fordi*, which in turn consume many more ants (45.7%) than *C. clayi* (only 9.5%). *C. fordi* eat 14.0% hemiptera and 11.8% wasps, as compared to only 7.6% and 3.4% respectively in *C. clayi*. *C. clayi* eat more termites (9.6%) and beetles (7.3%) than *C. fordi* (0.2%) and (2.8%), respectively. *C. clayi* has a broader dietary niche breadth (6.35) than *C. fordi* (3.96) which is an ant specialist.

ACKNOWLEDGEMENTS

H. L. Dunlap assisted greatly with field work. M. E. Egan and T. D. Schultz helped identify stomach contents. My research has been supported out of my own pocket and by grants from the National Geographic Society, the John Simon Guggenheim Memorial Foundation, a senior Fulbright Research Scholarship, the Australian-American Educational Foundation, the University Research Institute of the Graduate School at The University of Texas at Austin, the Denton A. Cooley Centennial Professorship in Zoology at The University of Texas at Austin, the U. S. National Science Foundation, and the U. S. National Aeronautics and Space Administration. I thank the staffs of the Department of Zoology at the University of Western Australia, the Western Australian Museum, and the Western Australian Department of Parks and Wildlife (previously Departments of Conservation and Environment or Conservation and Land Management (CALM)). Lizards were collected under permits issued by CALM/DEC and with the approval of appropriate animal ethics committees in both Australia and the University of Texas.

REFERENCES

BEARD, J. S. 1974. *Great Victoria Desert. The vegetation of the Great Victoria desert area.* (With maps.) Vegetation Survey of Western Australia, Nedlands.

HARRISON, S., D. MURPHY and P. R. EHRLICH. 1988. Distribution of the bay checkerspot butterfly, *Euphydryas editha bayensis*: Evidence for a metapopulation model. *American Naturalist* 132: 360–382.

LEVINS, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin*

Entomological Society of America 15: 237–240.

PIANKA, E. R. 1986. *Ecology and Natural History of Desert Lizards. Analyses of the Ecological Niche and Community Structure*. Princeton University Press, Princeton, New Jersey.

PIANKA, E. R. 1996. Long-term changes in Lizard Assemblages in the Great Victoria Desert: Dynamic Habitat Mosaics in Response to Wildfires. Chapter 8 (pp. 191–215) in M. L. Cody and J. A. Smallwood (eds.) *Long-term studies of vertebrate communities*. Academic Press.

PIANKA, E. R. 2014. Rarity in Australian desert lizards. *Austral Ecology* 39, in press.

PIANKA, E. R. 2013. Notes on the ecology and natural history of two uncommon arboreal agamid lizards *Diporiphora paraconvergens* and *Lophognathus longirostris* in the Great Victoria desert of Western Australia. *Western Australian Naturalist*, in press.

PIANKA, E. R. and S. E. GOODYEAR. 2012. Lizard responses to wildfire in arid interior Australia: Long-term experimental data and commonalities with other studies. *Austral Ecology* 37: 1–11.

SHEPHARD, M. 1995. *The Great Victoria Desert*. Reed Books, Chatswood, NSW.

SIMPSON, E. H. 1949. Measurement of diversity. *Nature* 163, 688.

AQUATIC MACROPHYTES IN THE GREAT VICTORIA DESERT

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ABSTRACT

Morphometric and water quality data are provided for a flooded rockhole in the Great Victoria Desert which holds water for exceptionally long periods. This rockhole contains an abundance of two aquatic macrophytes: *Ottelia ovalifolia* ("Swamp Lily") and *Potamogeton* sp. This *O. ovalifolia* population is isolated from other populations by at least several hundred kilometres.

INTRODUCTION

Located well within the confines of the Western Australian sector of the Great Victoria Desert (at *ca* 28°00"S, 124°40"E) is an extraordinary aquatic habitat which, though small, is long-lasting and usually contains a profusion of aquatic higher plants. Located on Hanns Track, this large rockhole was, very appropriately, called Lily Rockhole by the explorer Frank Hann in 1903 (Donaldson and Elliot 1998). During the winter of 2010 this flooded rockhole was sampled for invertebrates the nature of which was discussed by Bayly *et al.* (2011). Although this invertebrate study made passing reference to the aquatic plants, no detailed information about them was given. The purpose of this paper is to rectify this deficiency, and provide basic information about morphometric and physico-chemical aspects of this highly unusual habitat.

HABITAT

Although not of volcanic origin, Lily Rockhole (Fig. 1) resembles a miniature caldera with characteristic steep sides. When examined on 26 August 2010, the maximum length of the roughly ovoid pool was 4.0 m and the maximum width (at right angles to the line of maximum length) was 3.1 m. The maximum depth was 83 cm. The water was very fresh – conductivity (K25) only 155 µS cm^{-1} and corresponding

Figure 1. A view of Hanns Lily Rockhole from an elevated point on the northwest edge of the rockhole. The photograph taken 26 August 2010 shows that about a third of the water surface area is in deep shade. Photo: I. Elliot.

total dissolved solids (TDS) only about 100 mg L^{-1}. It is estimated that the rockhole contained close to 6 m^3 (6,000 L) of water. On 26 August 2010 the water level was 20 cm below the level of the rocky outlet or overflow gutter. Hence the maximum potential depth is 1.03 m. When completely full, it is estimated that it would hold approximately 7 m^3 (7,000 L) of water.

MACROPHYTES

When visited, the surface area of the water was close to 10 m^2 and this was largely covered by the floating leaves of two different species of macrophytes leaving only about 25% of open water. The larger macrophyte, *Ottelia ovalifolia* (R. Br.) L.C. Rich ("Swamp Lily"), had a leaf length in the range 14–19 cm, a petiole length (from roots to leaves) of 50–70 cm, and was growing in the deeper water. The smaller macrophyte, *Potamogeton* sp., had a floating leaf length in the range 5–7 cm, a stem plus petiole length to floating leaves of about 40 cm, and was growing in shallow water near the edge of the rockhole. [*Potamogetom* sp. also has long, slender, transparent, submerged leaves.]

Two specimens of each macrophyte species were detached from the substratum, floated onto a vinyl sheet, measured, photographed (whole specimens plus close-ups of leaves, petioles and flower buds), and returned to the rockhole.

O. ovalifolia occurs in all mainland States and the NT. It also occurs in New Caledonia and was introduced in 1897 to New Zealand. *Potamogeton* is widely distributed (Aston 1977).

DISCUSSION

Lily Rockhole is, as Hann himself fully realized, not a gnamma. Hann used the tautological term "namma hole" frequently in his 1903 diaries (Bayly 2011 p.42) but avoided it for Lily Rockhole. Gnammas are produced mainly by aqueous chemical weathering which produces basins with relatively smooth surfaces. The exact mode of origin of Lily Rock hole is unclear but its angular surfaces are not consistent with gnamma-formation.

Hann's companion, Talbot, first encountered this "splendid rock hole" on 23 May 1903 (Donaldson and Elliot 1998 p.153), and in July and October 1903, Hann pointedly referred to it as "Lilly (*sic*) Rock Hole". It seems a reasonable assumption, therefore, that one or other or perhaps both of the macrophyte species were there more than a hundred years ago when Hann and Talbot first camped there. In that *Potamogeton* sp. would not normally be described as a "waterlily" (unlike *Ottelia* it does not have a large, showy flowers), it is unlikely that this species alone was there in 1903.

Hann commented (Donaldson and Elliot 1998 p.153): "I think water is always there." Whilst this statement may have gone too far, there is now good evidence that wet periods for this rockhole are long and exceptionally persistent for a desert rockhole. Even when full, the surface waters are well sheltered through being surrounded on the northern and western sides by a vertical rock wall that ensures that much of the surface is shaded for much of the day. Over the 17-year period 1993–2010 one of us (I.E.) made ten winter visits to Lily Rockhole and on only one of these, that in June 2005, was there no water and no green macrophytes. Rainfall data for Laverton show that during the five months preceding June 2005 only 22 mm were recorded, and that the total for the year 2005 was only 121 mm as against the long term annual average of 232 mm. At Warburton Airfield, rainfall for the five months preceding June 2005 amounted to only 6 mm (Australian Government Bureau of Meterology 2013).

The observation that the rockhole was dry on 7 June 2005, but that abundant macrophytes were again present on all five consecutive yearly visits during the period 2006–2010 inclusive, indicates that *O. ovalifolia* and *Potamogeton* sp. have propagules

that can tolerate some degree of desiccation and re-establish a population with the arrival of a new hydro-period. This ability permits *Potamogeton* sp. to occur sporadically at Knight Gnamma Holes 25 km south of Lily Rockhole, and a more persistent population of this species occurs in an unnamed rockhole 313 km to the west at East Terrace 45 km north-east of Leonora.

Hann's Lily Rockhole is separated by the best part of a thousand kilometres from permanent or semi-permanent fresh waters in the high rainfall areas of south-western Australia that are likely to contain persistent populations of *O. ovalifolia*. It is almost 700 km outside the boundary of the relatively well-watered South-west Botanical Province (roughly the area lying to the south-west of a line drawn between Shark Bay and Israelite Bay) and far removed from the mainly coastal records for this species in this Province shown by Western Australian Herbarium (2013). According to the Florabase at the Western Australian Herbarium, *Ottelia* sp. was collected from "Hidden Secret Rock Hole" in [near?] the Yeo Lakes Nature Reserve in May 2011. However, since Lily Rockhole is located only 8 km from the eastern boundary of this reserve, a strong suspicion arises that the misnamed "Hidden Secret Rock Hole" is none other than Lily Rockhole, and that the reserve name was used as an approximate indication of the location. The collection mentioned in Florabase cannot now be located in the Herbarium (K.F. Kenneally, pers. comm. June 2013) [The Florabase record is apparently the product of a confused collector. Hidden Secret Rockhole is a real place but is near Lake Rawson, not Yeo Lakes Nature Reserve. It has been visited by one of us (I.E.) four times in different years but contained no macrophytes on the three occasions it was full of water.]

The intriguing question arises as to how *O. ovalifolia* was first introduced into this remote rockhole. Given the existence of propagules with some degree of resistance to desiccation, passive dispersal could have occurred in a number of ways. The potential role of waterbirds in dispersing plants in arid Australia was discussed by Green *et al.* (2008). However, the possibility of anthropogenic intervention cannot be ruled out. It is not inconceivable that the rootstock of *Ottelia* (and possibly also that of *Potamogeton* despite being less fleshy) was used as a minor source of food, to supplement desert animals and terrestrial plants, by Aborigines who camped there and produced the rock art on an overhang only 50 m from the rockhole. Aboriginal use of the fleshy parts of freshwater macrophytes for food is well documented. Irvine (1957), for example, showed that Aborigines consumed the tubers of *Aponogeton elongatus*.

ACKNOWLEDGEMENTS

We thank Dr Michelle Casanova of the National Herbarium of Victoria, Royal Botanic Gardens Melbourne, for examining a series of photographs to confirm our own tentative identifications of the macrophytes. We also thank a referee for very helpful input.

REFERENCES

ASTON, H.I. 1977. *Aquatic Plants of Australia.* Melbourne University Press, Carlton.

AUSTRALIAN BUREAU OF METEROLOGY 2013. Station numbers 012045 and 013011 – Laverton and Warburton Airfield. Monthly rainfall data. http://www.bom.gov.au/climate/data. Accessed 11 June 2013.

BAYLY, I.A.E. 2011. *Australia's Granite Wonderlands.* Bas Publishing, Seaford.

BAYLY, I.A.E., HALSE, S.A. and TIMMS, B.V. 2011 Aquatic invertebrates of rockholes in the south-east of Western Australia. *Journal of the Royal Society of Western Australia* **94**: 549–555.

DONALDSON, M. and ELLIOT, I. (Eds) 1998. *Do Not Yield to Despair: Frank Hugh Hann's Exploration Diaries in the Arid Interior of Australia 1895–1908.* Hesperian Press, Carlisle.

GREEN, A.J., JENKINS, K.M., BELL, D., MORRIS, P.J. and KINGSFORD, R.T. 2008 The potential role of waterbirds in dispersing invertebrates and plants in arid Australia. *Freshwater Biology* **53**: 380–392.

IRVINE, F.R. 1957. Wild and emergency foods of Australian and Tasmanian Aborigines. *Oceania* **28**, 113–142.

WESTERN AUSTRALIAN HERBARIUM 2013. Distribution map for *Ottelia ovalifolia.* http://florabase.dec.wa.gov.au/browse/map/168 Accessed 12 March 2013.

NOTES ON THE NATURAL HISTORY OF THE RARELY RECORDED AGAMID LIZARD *CAIMANOPS AMPHIBOLUROIDES* IN WESTERN AUSTRALIA

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ABSTRACT

Ecological data on the seldom encountered and little known agamid *Caimanops amphiboluroides* are presented. *Caimanops* is arboreal and is usually associated with mulga trees and fence posts. Average height above ground of 10 active lizards was 79.5 cm. Average body temperature of 13 active lizards was 36.6°C. These lizards are dietary specialists, feeding mostly on termites. Average clutch size is 12 (N=2).

INTRODUCTION

Caimanops is a monotypic genus found only in Western Australia (Cogger 2000, Storr 1974). During 1967–1968, my field assistant and I encountered a small population of these elusive agamids at the Atley area (Lat. 28° 27' x Long. 119° 05'). This sample was augmented with a few others collected incidentally on nearby areas.

METHODS

We recorded air and body temperatures, activity time (decimalized for statistical convenience), microhabitat, fresh snout-vent length (SVL), tail length, and weight for as many lizards as possible. Stomach contents were identified and prey volumes estimated for all lizards collected [some of these data were summarized in appendices in Pianka (1986)]. Dietary niche breadth was calculated using the inverse of Simpson's (1949) index of diversity [$D = 1/ \Sigma p_i^2$] where p_i is the proportion of prey category *i*.

RESULTS

Size. Snout-vent lengths ranged from 38 to 99 mm. Females averaged 81.4 mm, males 76.7 mm.

Microhabitat. Most *Caimanops* were from 60 to 120 cm above ground (mean = 79.5, N = 10) when first encountered (Figure 1). Most were facing upwards. Of three that were on the ground,

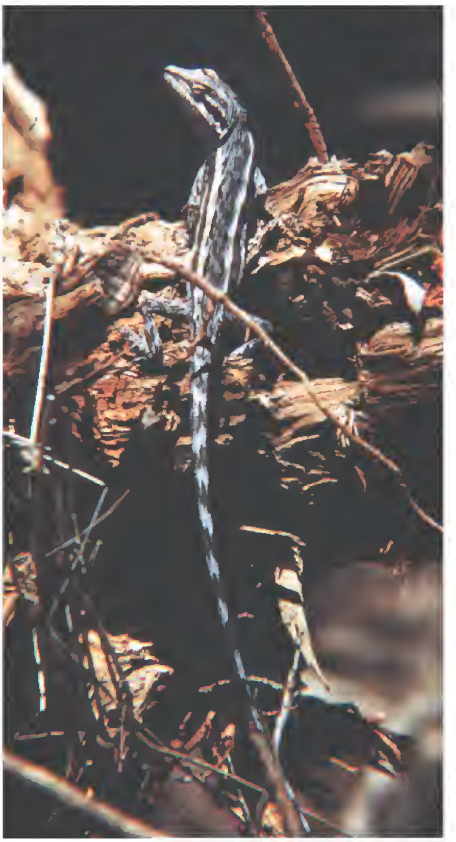

Figure 1. *Caimanops amphiboluroides.*

presumably foraging, one was under a small bush in the shade, another was in the open shade and ran to a clump of grass, a third was in the open sun and walked to open shade, then ran to the edge of open sun/shade.

Time of Activity. *Caimanops* were active during the middle of the day from 10.25 to 17.7hr. (Average =13.9) see Figure 2).

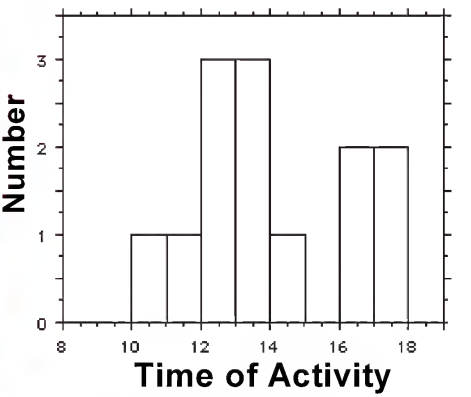

Figure 2. Histogram of times of activity (N=13).

Table 1. Summary of stomach contents of 13 *Caimanops*.

Prey Category	Number	Number %	Volume	Volume %	Frequency
Centipedes	2	0.21	0.25	2.48	2
Ants	52	5.39	0.56	5.54	8
Locustids	1	0.10	0.3	2.97	1
Isoptera	892	92.54	6.71	66.44	10
Dermaptera	1	0.10	0.02	0.20	1
Larvae	1	0.10	0.2	1.98	1
Other Insects	1	0.10	0.05	0.50	1
Vegetative	6	0.62	0.85	8.42	6
Unidentified	8	0.83	1.16	11.49	8
Total	964	100.00	10.1	100.00	38

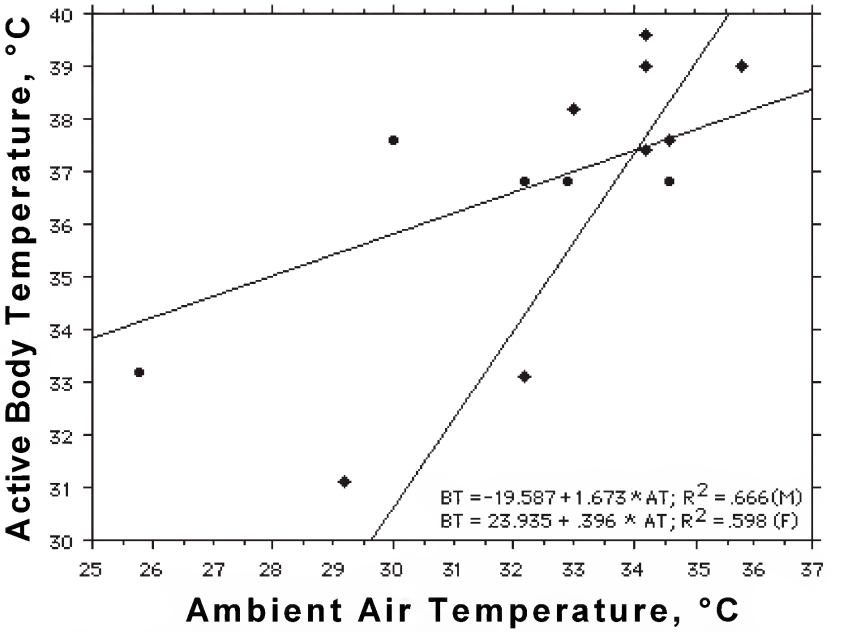

Figure 3. Body temperatures plotted against ambient air temperature for 13 *Caimanops*. Circles represent 5 females, 8 males shown as diamonds. Least squares regression lines are shown for each sex and equations are given at the bottom right.

Thermal Relations. As in most diurnal desert lizards, active body temperatures of *Caimanops* are positively correlated with ambient air temperatures (Figure 3). Average body temperature of 13 active lizards was 36.6°C. Average for 5 adult females was 36.2°C and for 8 males including two juveniles was 36.9°C. Many males had slightly higher body temperatures than females.

Diet. *Caimanops* is a termite specialist with a narrow dietary niche breadth of 2.14 (Table 1). Six individuals had eaten small amounts of vegetative material.

Reproduction. Two females collected in December contained enlarged yolked follicles in their ovaries but none were found with shelled eggs in their oviducts. Clutch sizes appear to be large: 10 and 14. Average snout vent length (SVL) of these two adult females was 95 mm. Average SVL of three adult males was 84.3 mm.

DISCUSSION

Caimanops amphiboluroides is among the rarest and least encountered species of Australian desert lizards (Pianka 2011, 2014). Present at very low density at only one of my ten study sites, it is also a dietary specialist with

high niche overlap with many other species, all factors that could contribute to its rarity.

ACKNOWLEDGEMENTS

H. L. Dunlap provided companionship and assistance in the field. A. R. Main of the Department of Zoology at the University of Western Australia sponsored me and offered invaluable advice and tips for how to cope with living in the bush. G. M. Storr of the Western Australian Museum helped greatly as well. Stomach contents were identified by M. E. Egan. V. Johnson Dennison assisted with dissections, data, and laboratory analyses. Editor John Dell made many suggestions for improvements. This research was supported by grants from the US National Institute of Health and the US National Science Foundation. Specimens are housed in the Los Angeles County Museum of Natural History.

REFERENCES

COGGER, H. G. 1992. *Reptiles and Amphibians of Australia*, 5th ed. Reed Books. 775 pp.

PIANKA, E. R. 1986. *Ecology and Natural History of Desert Lizards. Analyses of the Ecological Niche and Community Structure.* Princeton University Press, Princeton, New Jersey.

PIANKA, E. R. 2011. Notes on the ecology of some uncommon skinks in the Great Victoria Desert. *Western Australian Naturalist* 28: 50–60.

PIANKA, E. R. 2014. Rarity in Australian Desert Lizards. *Austral Ecology* 39: in press.

SIMPSON, E. H. 1949. Measurement of diversity. *Nature:* 163: 688.

STORR, G. M. 1974. Agamid lizards of the genera *Caimanops, Physignathus* and *Diporiphora* in Western Australia and the Northern Territory. *Records of the Western Australian Museum* 3: 121–146.

STATUS OF THE AIRLIE ISLAND CTENOTUS, *CTENOTUS ANGUSTICEPS* (LACERTILIA: SCINCIDAE), WITH NOTES ON DISTRIBUTION, HABITAT AND GENETIC VARIATION

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ABSTRACT

The scincid lizard, *Ctenotus angusticeps* was previously only known from a single island (Airlie Island) and two disjunct mainland localities in Western Australia. As a result of its restricted distribution and little documentation, it has for some time been listed under both state and federal legislation. Recent surveys have revealed additional populations along the northwestern coast, which appear to be highly restricted to specific habitats, primarily salt marsh communities adjacent to mangroves where lizards shelter down crab holes. Genetic analysis of mitochondrial DNA shows very little variation between populations, suggesting a single widespread population or recent radiation. In light of this additional information the conservation status of *C. angusticeps* is evaluated.

INTRODUCTION

The scincid genus *Ctenotus* is Australia's most diverse with currently 103 described species (Wilson and Swan 2013) displaying frequent sympatry and morphological similarity. As a result, numerous studies on habitat separation and ecological interactions have been carried out (e.g. Read 1998; James 1991; Sadlier 1987; Pianka 1986). However, for many species, published ecological data is minimal with their species descriptions representing the only source of available information.

Ctenotus angusticeps was first described by Storr (1988) from a series collected during a biological survey on Airlie Island, 35km NNE of Onslow on the northwestern coast of Western Australia (Figure 1). Presumably due to its restricted distribution on a small island (0.28km^2) and the comments made by Browne-Cooper and Maryan (1990)

Figure 1. Updated distribution map for *Ctenotus angusticeps* showing a very discontinuous range along the northwestern coast of Western Australia due to an association with a very specific habitat. Abbreviations: Ck: Cape Keraudren, Ps: Port Smith, Th: Thangoo, Cc: Crab Creek, Wc: Willie Creek.

regarding habitat disturbances at the island, this species was listed as 'Threatened' in Western Australia [under the Wildlife Conservation Act Specially Protected Fauna Notice in 1990]. Since this listing, *C. angusticeps* has been found on the mainland at two very disjunct coastal localities, one on Thangoo Station, at the southern end of Roebuck Bay in the Kimberley region (Sadlier 1993) and the other at Port Hedland in the Pilbara region (Turpin and Ford 2011). Both mainland accounts provide information on ecology and habitat and make morphological comparisons between known populations. Currently, *C. angusticeps* has both a state and federal listing as Schedule 1 under the Wildlife Conservation Act 1950 and Vulnerable under the Environment Protection and Biodiversity Act 1999. Two other restricted range *Ctenotus* species *C. lancelini* and *C. zastictus* have the same listings.

Due to its perceived vulnerable status, one of the stipulated research priorities for *C. angusticeps* is to undertake survey work to locate additional populations in the intervening areas and determine the dis-

tribution of *C. angusticeps* along the northwestern coast of Western Australia (Threatened Species Scientific Committee 2008). Considering the distance between the two mainland localities and the lack of survey effort in its documented habitat thus far by experienced field zoologists, it seemed highly likely that additional populations would be located. Due to recent finding of *C. angusticeps* at Port Hedland (Turpin and Ford 2011), an area undergoing rapid port and/or infrastructure development by mining companies, a reconnaissance survey was conducted in December 2011 to determine its local distribution, relative abundance and habitat preference. This was followed by a broader-scale survey in May 2012, covering much larger areas to the north and south of Port Hedland to search for additional populations. Here we report on results of a targeted survey from Onslow to Broome in May 2012, presenting new location records, molecular examination of known populations and further notes on habitat preferences and other observations. We also provide a suggestion of a common name change and a discussion relating to its current conservation status.

METHODS

Experienced field zoologists familiar with the identification of *Ctenotus* spp. and with considerable survey experience conducted daytime searches for *C. angusticeps* from 2–10 May 2012. This involved two teams of three people investigating areas of potential suitable habitat as described by Sadlier (1993) and Turpin and Ford (2011), and the immediate surrounding habitats between Onslow and Broome. Potential habitat was initially examined using vegetation maps, aerial imagery and Google Earth imagery, and permission was sought from landowners to conduct any surveys on private land.

Searching methods involved slowly walking through areas considered suitable and visually observing active lizards until a positive identification was made. Once confirmed, attempts to capture some individuals were made by hand or by using a circular metal ring to entrap a lizard within low vegetation. Due to the extensive survey area to be assessed and time restraints, the use of more permanent trapping techniques was not feasible.

Photographic records were taken of the habitats where *C. angusticeps* were found along with images of individual lizards from most localities. Tissue samples (tail-tips) were taken from ten *C. angusticeps* captured, and representative voucher specimens were also collected and lodged with the Western Australian Museum (Tissues R634–43; Specimens R172522, R172876–78). Each lizard captured was then weighed, measured and released at capture

site. The retention of tissue and specimens was done in accordance with Regulation 17 licence to take fauna for scientific purposes (Number SF008623) issued by the Department of Environment and Conservation, Western Australia.

We analysed 580 base pairs of mitochondrial DNA for the ND2 gene from thirteen individuals, the rate of change in this mitochondrial locus has been estimated to be c. 1.3–1.4% Myr in other skink species (Macey *et al.* 1997; Greaves *et al.* 2008). DNA was extracted using DNeasy tissue extraction kits (Qiagen) and the primers ND2 L4437 (Macey *et al.* 1997) and ND2r102 (Sadlier *et al.* 2004) were used. Standard PCR thermocycling protocols were used and amplicons were purified using either ExoSap-IT (USB Corporation, OH, USA) or QiaQuick PCR clean up (Qiagen). Purified templates were sequenced in both directions by Macrogen (Seoul, Korea). Sequences were edited and aligned with Sequencher v. 4.10 (Gene Codes, Ann Arbor, MI) and Geneious v5.5.6. Pairwise sequence divergence was calculated using MEGA 5. JModel test (Posada 2008) favoured an GTR+G model for the ND2 mtDNA data and accordingly MrBayes (Huelsenbeck and Ronquist 2001) was used to generate a maximum *a postori* tree (2.2 million iterations with 10% burnin) where parameters were surveyed (through ESS values) to ensure appropriate mixing. A sequence of *Ctenotus robustus*, the closest *Ctenotus* for which ND2 has been sequenced, was downloaded from GenBank (AY662548) and incorporated into the alignment as an outgroup.

NEW LOCATION RECORDS

In the Port Hedland area, *C. angusticeps* was recorded at multiple localities, including

Table 1. Summary of new location records for *C. angusticeps* recorded in May 2012.

LOCATION	DATE
Pretty Pool, Port Hedland	02/05/2012
Wedgefield, Port Hedland	02/05/2012
Redbank, Port Hedland	03/05/2012
Finucane Island, Port Hedland	03/05/2012
Boodarie Station, 12 and 16km W Port Hedland	03/05/2012
Lulu Creek, 7km E Karratha	06/05/2012
Beebingarra Creek, 15km E Port Hedland	03/05/2012
Cape Keraudren, 9km N Pardoo Roadhouse	04/05/2012
Port Smith, 25km NE Bidyadanga Community	07/05/2012
Thangoo Station, 28km SSE Broome	08/05/2012
Crab Creek, 16km ESE Broome	08/05/2012
Willie Creek, 25km N Broome	08/05/2012

Redbank (Turpin and Ford 2011), Finucane Island, Pretty Pool and Wedgefield. The species was also recorded immediately west of Port Hedland on Boodarie Station and east at Beebingarra Creek. We also recorded *C. angusticeps* from near Karratha, Cape Keraudren, Port Smith, Thangoo Station (Sadlier 1993) and both Crab and Willie Creeks in the Broome area (Table 1, Figure 1).

SEQUENCE DIVERGENCE

Intraspecific variation in the ND2 gene fragment for *C. angusticeps* sampled from sites throughout their known range (Figure 2) up to 850 km apart was small; the thirteen sequences were 99.3% identical across the 580 nucleotide positions. The pairwise distance (using multiple models) in the ND2 gene was uniformly low ~ 0.6%. While the Airlie Island population share a haplotype (based on a single transversion), the clade is embedded within the mainland diversity. The ND2 gene region used here has been investigated in other skink species where clades within the same species were much greater than observed

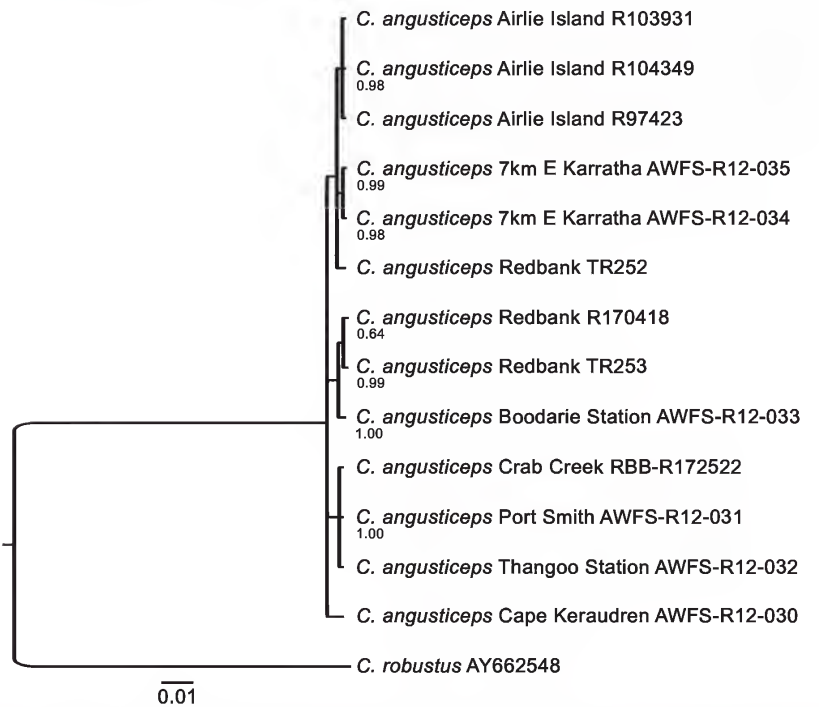

Figure 2. Maximum *a postori* tree of *Ctenotus* ND2 sequence. The tree was constructed in MrBayes (Huelsenbeck and Ronquist 2001) using thirteen *C. angusticeps* sequences (580 bp) along with *C. robustus* (AY662548) as the nominated outgroup. Posterior probabilities are shown on the nodes.

here (Greaves *et al.* 2008). Taken together the data suggest the sampled populations are conspecific. While the mtDNA ND2 genetic distance is very shallow it is acknowledged that to more accurately map the extent of gene flow between populations that polymorphic markers (such as STR's) may need to be evaluated. ND2 sequences have been deposited on GenBank with accession numbers (KF537351–KF537363).

HABITAT AND ENVIRONMENT

Ctenotus angusticeps has been previously recorded as occurring in most habitat types on Airlie Island, such as tussock grasslands and *Acacia coriacea* shrubland with coastal Spinifex (Browne-Cooper and Maryan 1990), however this differs markedly to the vegetation occupied on the mainland at Roebuck Bay (Sadlier 1993). Turpin and Ford (2011) provided a detailed description of the habitat where *C. angusticeps* was recorded at Port Hedland that is consistent with the 'samphire shrubland along a mangrove margin' described by Sadlier (1993). Our survey effort was concentrated in these 'salt marsh communities' on the landward fringe of mangroves, which are numerous and patchy along the northwestern coast sometimes forming large vegetation communities (Van Vreeswyk *et al.* 2004). Although the habitats on Airlie Island and the mainland are markedly different, the primarily coastal distribution of *C. angusticeps* may suggest that the 'salt marsh communities' are the ancestral habitat of this species, with arguably the island population secondarily adapting to the habitat now present on the island. This fragmented distribution is mirrored in other fauna such as the legless lizard *Delma borea* and the murid rodent *Pseudomys nanus*, which also have relictual populations on islands off the Pilbara coast (Maryan *et al.* 2007).

Our observations confirm that *C. angusticeps* is very habitat specific, occupying areas broadly described as the landward fringe of salt marsh communities, vegetated with samphire and marine couch grass immediately adjacent to mangroves or some distance away, though still within close association. The dominant vegetation being the succulent samphires *Tecticornia halocnemoides* subsp. *tenuis* and *Suaeda arbusculoides* on clayey soils with a mixed herb and grass cover of *Muellerolimon salicorniaceum* and *Sporobolus virginicus* on sandy soils (Beard 1990). *Ctenotus angusticeps* was

Figure 3. The habitat at some of the locations where *C. angusticeps* were recorded showing the subtle differences in structure of samphire and marine couch grass on a sandy clay substrate with numerous crab holes. All locations become inundated during very high tides, (A) Karratha, (B) Cape Keraudren, (C) Crab Creek. ▶

A

B

C

observed at some localities within the mangrove-lined creek edges but displayed a marked preference for the low open shrubland area that is subject to tidal influences with numerous crab holes on a heavy, greyish sandy clay substrate. At some locations where low sandy rises persisted with dense vegetation, especially marine couch grass, *C. angusticeps* was more numerous. These areas either formed a raised 'island' surrounded by bare, sparsely vegetated mud flats or a narrow strip (< 10m) growing through the samphire. Overall, the general structure of the samphire did vary subtly from very low, dense clumps interspersed with marine couch grass to very flat, prostrate clumps or medium-high shrubs surrounded by bare ground (Figures 3A–C).

Despite the apparent suitability of the habitat, *C. angusticeps* was not observed in the marginal, sandier *Triodia*-dominated vegetation, where other species such as *C. saxatilis* and *C. pantherinus* were prevalent. The occasional *C. saxatilis* was observed in the same habitat as *C. angusticeps*, particularly in the Port Hedland area, though in fewer numbers. An apparent barrier may be the Eighty Mile Beach area (Figure 1), where no *C. angusticeps* were detected, despite the presence of flat coastal plains of clayey sand with some samphire and marine couch grass; however there were no substantial mangroves with associated crab holes. We also did not record any *C. angusticeps* at Derby, where ample mangroves and tidal creeks margin the King Sound. However from our observations, the extreme landward fringes of salt marsh communities were devoid of crab holes and appeared unsuitable for this species. We did however; observe the abundant species *C. inornatus* in these areas.

The salt marsh communities inhabited by *C. angusticeps* are associated with the more extensive mangrove communities, which are typically coastal plants subject to periodic tidal inundation and exhibit a number of anatomical adaptations and physiological characteristics which enable them to flourish under these conditions (Semeniuk *et al.* 1978). Not only is this saline environment harsh, subjected to extreme heat, wind, glare and tidal influences, it is also dynamic by virtue of the ever encroaching movement and recruitment of mangroves into new adjacent areas that are dependant on water levels and the effects of erosion. The mangroves are interconnected with the landward salt marsh communities by trapping sediment and creating areas of sand deposition for samphire and other species to grow. Therefore, it is feasible to assume that the environment for *C. angusticeps* would expand and contract over relatively short periods of time connecting and isolating lizard populations on a regular basis and correspondingly, if *C. angusticeps* were reliant on crab

holes (see notes below) for shelter, then the creation of these holes would fluctuate seasonally and possibly change from year to year.

USAGE OF CRAB HOLES

At all locations where *C. angusticeps* was detected, crab holes of varying sizes were present and as reported by Turpin and Ford (2011), these were often used by skinks to take shelter, evading our attempts to capture them. Initially, when adult lizards were observed they took shelter at the base of low vegetation, followed by retreating down a hidden hole among the samphire and marine couch grass. By contrast, juvenile lizards usually relied on the protective cover of the vegetation to avoid capture, often taking refuge amongst the dense tussocks of marine couch grass. They would do this with some ease and after being pursued, later being located deep within the tussock. In addition, both adults and juveniles were sometimes observed to retreat up into samphire vegetation, sometimes up to 30cm above the ground. Thus, this species seems to be opportunistic in selecting retreat sites upon pursuing, and the tendency and ability of lizards to utilise a range of refuge types, both above and below ground level, may be of great advantage in a relatively open environment where vulnerability to predation could be high.

To test whether lizards would utilise the crab holes even in the absence of perceived threat of being captured by us, we used a non-toxic fluorescent powder (Radiant Colour Series Tl, DayGlo Colour Corporation, Ohio) to track their movements. Two adult *C. angusticeps* at Redbank near Port Hedland caught early in the day were dipped in the 'powder' and released shortly afterwards (methodology adopted from Stark and Fox 2000; Bernd and Henle 2004). The next morning we tracked their movements from the previous day to separate crab holes where lizards sheltered overnight, showing that the lizards are using crab holes by choice.

In highly exposed and harsh environments, burrows and holes created by other animals would provide effective protection to lizards (Davidson *et al.* 2008). Many other species of *Ctenotus* shelter down holes, mainly excavated by insects, or by themselves (Taylor 1984) especially in areas where the abundance of cover in the form of rocks, logs, leaflitter, various hummock grasslands and deep earth cracks is less (B. Maryan and R. Lloyd pers. obs.). Similarly, there is minimal effective shelter where the *C. angusticeps* live apart from the crab holes and limited dense vegetation, thus the former could be an essential criterion in their habitat selection. In areas where there was artificial shelter (e.g. pieces of

driftwood), some skinks took shelter beneath these, but they eventually disappeared down a crab hole.

Another interesting observation made regarding the use of crab holes was at Port Smith, where a lizard was observed entering a low, prostrate samphire on an incoming tide that soon became submerged without the lizard being re-sighted. After the tide receded, we continued our searches on the recently inundated ground that was very damp underfoot and sighted several active *C. angusticeps*. We assumed at the time, that the lizards were down crab holes, possibly utilising air pockets to sustain their residence, however this requires further investigation. The use of crab holes by reptiles in areas subjected to periodic inundation has been documented previously for other species of Australian reptiles occurring in tidal/mangrove communities (e.g. *Fordonia leucobalia*, *Myron richardsonii*: Gow 1989; Cox 1991; Karns *et al.* 2005; Murphy 2007; R. Somaweera pers. obs.). In southwestern Western Australia, the skink *Lissolepis luctuosa* and snake *Elapognathus minor*, species that do inhabit seasonally inundated wetlands, have been found in completely submerged freshwater crayfish holes (B. Maryan pers. obs.). Burrows of other crustaceans in mangrove communities are also used by an array of invertebrates (Ng and Kang 1988), fish (Al-Behbehani and Ebrahim 2010; Berti *et al.* 2008), frogs and other lizards elsewhere (Ng and Sivasothi 1999).

The apparent high frequency of crab hole usage by lizards in the salt marsh communities lead us to believe that these were an essential requirement for this species. This is reinforced further by not observing any *C. angusticeps* in areas without crab holes. Mangrove crabs could be considered as 'ecosystem engineers', a group of animals that physically create, maintain and modify their environment (Jones *et al.* 1994). Hence the spatial distribution and abundance of species that utilise these holes could vary with the distribution of the particular species of crabs. The crab species inhabiting the northwestern coastline of Western Australia are diverse with many specific to mangroves and associated salt marsh communities (Jones and Morgan 1994). The most likely species digging the holes, where we observed *C. angusticeps* are the Fiddler *Uca* spp. and Bubbler Crabs *Scopimera* spp. Further studies are required to investigate whether the distribution of *C. angusticeps* is correlated to distribution of any particular type of crab as shown for some other species (e.g. Subramanian 1984; Berti *et al.* 2008).

ACTIVITY

Ctenotus species are typically diurnal, but some display

nocturnal activity and are generally notoriously difficult to observe due to their cryptic nature. They maintain high average active body temperatures of 30–38°C (Greer 1989), and because the air and ground temperatures are time-dependent, the temporal activities of different species must be closely 'geared' to their thermoregulatory requirements. *Ctenotus angusticeps* inhabits an environment subjected to very high daytime temperatures with strong solar radiation. Observations made during our survey show that *C. angusticeps* can tolerate very high ground temperatures and thus be active throughout the day, moving at great speed from one clump of vegetation to the next. Even though May is considered to be a cooler time of the year along the northwestern coastline of Western Australia, we still recorded ground temperatures of 41–45°C when *C. angusticeps* was actively foraging. Due to the scope and size of the survey area between Onslow and Broome, areas considered suitable were surveyed at different times of the day (extended into the twilight hours), and individuals were still observed. However it is likely that more activity is concentrated in the early mornings and late afternoons (Browne-Cooper and Maryan 1990; Sadlier 1993), in accordance with the bimodal daily activity pattern shown by many lizards during warmer times.

The long diurnal period of activity observed by us could be an adaptation to increased foraging efficiency in a highly fluctuating environment. We observed individuals foraging both on the raised sandy patches and among the pneumatophores of mangrove plants during low tide. While no records of their diet exist, it is likely that they are opportunistic feeders, like many other species in the genus (Twigg *et al.* 1996; Read 1998). Future studies could investigate how they manage the potently high salt levels in their bodies, as arguably a component of their diet may comprise intertidal invertebrates.

COLOUR AND PATTERN

The description of *C. angusticeps* by Storr (1988) was based on individuals collected from Airlie Island. The dorsal and lateral surfaces were described as dark olive grey with a mottled pattern consisting of black and whitish markings. These markings tended to be arranged on the side of the body in three series of 'ocelli', e.g. short, whitish longitudinally elongate bars laterally edged with black, and the dorsal pattern being vague, but with some indication of a black vertebral stripe. Although Storr (1988) stated that *C. angusticeps* had a pattern of 'ocelli' on the lateral surfaces, it is more obscure and irregular when compared to *C. pantherinus*, which has a clearly-defined series of longi-

A

B

C

tudinal, dark-edged white spots or bars (see Plate 6, Storr *et al.* 1999). In general appearances, the pattern of *C. angusticeps* is more similar to *C. grandis*, a widespread arid-adapted species also flecked with white on the lateral surfaces.

Based on the description by Storr, comments by Sadlier (1993) and Turpin and Ford (2011), and our recent observations, it seems that *C. angusticeps* has consistent colouration and pattern morphology. This can be described as a faintly mottled pattern, particularly in adults, of short whitish to cream flecks or bars intermixed with blackish markings that tend to align longitudinally on the dorsal surfaces to form a vertebral stripe often extending along the tail, on an olive-grey or greyish to light brown ground colour (Figure 4). In some adult individuals at Karratha and Cape Keraudren, the lateral pattern is very weak with a strong indication of a vertebral stripe (Figures 4A–B), while others at Crab Creek had a bolder pattern (Figure 4C) similar to the juvenile colouration described by Turpin and Ford (2011). At all localities where *C. angusticeps* was observed, this colouration afforded them excellent camouflage on the sandy clay substrate when lizards 'froze' amongst the vegetation.

NEW COMMON NAME SUGGESTION

Given that *C. angusticeps* is now known from a much broader (albeit patchy) distribution on the coastal mainland in the Kimberley and Pilbara biogeographic regions and is a species that occurs in a very specific habitat different from most other *Ctenotus* spp. in Western Australia (Storr *et al.* 1999), we recommend changing the common name 'Airlie Island Ctenotus'. The continued use of this common name incorrectly implies that *C. angusticeps* only occurs on this island. Based on available knowledge and as proposed by Wilson and Swan (2013) the 'Northwestern Coastal Ctenotus' is an appropriate replacement name.

FUTURE AND CONSERVATION

The information collected on *C. angusticeps* during our survey has considerably added to the knowledge of this species. Prior to our surveys, the mainland distribution of *C. angusticeps* was only known from two very disjunct localities that were serendipitously made in a habitat that has received very little biological attention. This is underlined especially in the Pilbara, which is one of the most

◀ **Figure 4.** Representative *Ctenotus angusticeps* from three localities along the northwestern coast of Western Australia showing the subtle colour and pattern variation in dorsal and lateral surfaces, (A) Karratha, (B) Cape Keraudren, (C) Crab Creek.

intensely surveyed and collected areas in the state (How and Cowan 2006; Doughty *et al.* 2011).

Ctenotus, the most diverse skink genus in Australia, contain many species with extremely localised distributions due to an association with a specific habitat and/or microhabitat (Wilson and Swan 2013). *Ctenotus angusticeps* is an excellent example within this category as it is highly specialised in habitat selection. Hence, if the habitat is not 'foraged through' or 'systematically trapped' the species will continue to go undetected. Our targeted surveys employed a simple foraging technique that successfully addressed one of the crucial criteria's outlined for a conservation significant species, which is to 'undertake survey work in suitable habitat and potential habitat to locate any additional populations/occurrences (Threatened Species Scientific Committee 2008).

Since 1990, *C. angusticeps* has been listed on both state and federal legislation and it has taken 22 years to address a basic criterion on the mainland. We are also not aware of any research priorities investigating the abundance of this species on Airlie Island in this time. We believe the current listings for many of the 26 'threatened' and 48 'priority' reptile species in Western Australia under the various rankings are, at times ambiguous and can be inconsistent. If they are 'flagged' due to their conservation significance, then the threatening processes for most species should be considered and prioritised measures implemented to address the various criteria. Unfortunately this is not happening due in part to an anthropogenic bias towards avian and mammalian species. During a single survey we greatly expanded the known distribution for *C. angusticeps* and revealed a unique lifestyle of a lizard inhabiting a very harsh and dynamic environment subjected to tidal influences and utilising crab holes for shelter. Future studies on how this lizard interacts with its environment will have conservation and management benefits.

In light of this additional information, the conservation status of *C. angusticeps* requires evaluation. It shows a highly specialised skink inhabiting a naturally fragmented habitat along the northwestern coastline of Western Australia, and it is likely that *C. angusticeps* will be recorded at other locations between Onslow and Broome (possibly even further afield). However, we recommend that *C. angusticeps* retains its current 'Vulnerable' status for the following reasons:

- All known populations of this species remain fragmented.
- It is a very highly specialised lizard inhabiting an environment that is harsh and dynamic.
- The natural habitat of this

species is unique and fragmented within the landscape.

- Populations are not known to occur in any protected reserve system on the mainland.
- Relationship between lizards and its environment (e.g. apparent dependency on crab holes for shelter) and their responses to change in the environments is unknown and requires further study.
- The known habitat of this species is prone to development (ports, airports etc) and destruction (4WD vehicles and motorbikes), particularly in a large part of their known range around Karratha, Port Hedland and Broome.
- The habitats of this species are highly vulnerable to both extreme weather (e.g. floods) and potential effects of future climatic change (e.g. rises in the sea level).

ACKNOWLEDGEMENTS

We are grateful to B. Barnett of BHP Billiton Limited for her assistance during survey work and to J. Rowley of the Australian Museum for doing the preliminary genetic analysis. The permission and support we received from the station owners to search for skinks on their properties are appreciated.

REFERENCES

AL-BEHBEHANI, B.E. and EBRAHIM, H.M.A. 2010. Environmental studies on the mudskippers in the intertidal zone of Kuwait Bay. *Nature and Science* **8**: 79–89.

BEARD, J.S. 1990. *Plant Life of Western Australia*. Kangaroo Press, New South Wales.

BERND, G. and HENLE, K. 2004. Linking habitat structure and orientation in an arboreal species *Gehyra variegata* (Gekkonidae). *Oikos* **107**: 406–414.

BERTI, R., CANNICCI, S., FABBRONI, S. and INNOCENTI, G. 2008. Notes on the structure and the use of *Neosarmatium meinerii* and *Cardisoma carnifex* burrows in a Kenyan mangrove swamp (Decapoda Brachyura). *Ethology Ecology & Evolution* **20**: 101–113.

BROWNE-COOPER, R. and MARYAN, B. 1990. Observations on *Ctenotus angusticeps* (Scincidae) on Airlie Island. *Herpetofauna* **20**: 1–2.

COX, M.J. 1991. *The Snakes of Thailand and their Husbandry*. Krieger Publishing Co., Malabar, Florida.

DAVIDSON, A.D., LIGHTFOOT, D.C. and McLNTYRE, J.L. 2008. Engineering rodents create key habitat for lizards. *Journal of Arid Environments* **72**: 2142–2149.

DOUGHTY, P., ROLFE, J.K., BURBIDGE, A.H., PEARSON, D.J. and KENDRICK, P.G. 2011. Herpetological assemblages of the Pilbara biogeographic region, Western Australia: ecological associations, biogeographic patterns and conservation. *Records of the Western Australian Museum*, Supplement **78**: 315–341.

GOW, G. 1989. *Graeme Gow's Complete Guide to Australian Snakes.* Angus and Robertson Publishers, Northe Ryde, New South Wales.

GREAVES, S.N.J., CHAPPLE, D.G., DAUGHERTY, C.H., GLEESON, D.M. and RITCHIE, P.A. 2008. Genetic divergences pre-date Pleistocene glacial cycles in the New Zealand skink, *Oligosoma infrapunctatum*. *Journal of Biogeography* **35**: 853–864.

GREER, A.E. 1989. *The Biology and Evolution of Australian Lizards.* Surrey Beatty & Sons, New South Wales.

HOW, R.A. and COWAN, M.A. 2006. Collections in space and time: A biogeographical examination of native frogs, mammals and reptiles in Western Australia. *Pacific Conservation Biology* **12**: 111–133.

HUELSENBECK, J.P. and RONQUIST, F. 2001. MRBAYES: Bayesian inference of phylogeny. *Bioinformatics* **17**: 754–755.

JAMES, C.D. 1991. Temporal variation in diets and trophic partitioning by coexisting lizards (*Ctenotus*: Scincidae) in central Australia. *Oecologia* **85**: 553–561.

JONES, C.G., LAWTON, J.H. and SHACHAK, M. 1994. Organisms as ecosystem engineers. *Oikos* **69**: 373–386.

JONES, D.S. and MORGAN, G.J. 1994. *A Field Guide to the Crustaceans of Australian Waters.* Reed Books, Australia.

KARNS, D.R., MURPHY, J.C., VORIS, H.K. and SUDDETH, J.S. 2005. Comparison of semi-aquatic snake communities associated with the Khorat Basin, Thailand. *Natural History Journal of Chulalongkorn University* **5**: 73–90.

MACEY, J.R., LARSON, A., ANANJEVA, N.B. and PAPENFUSS, T.J. 1997. Evolutionary shifts in three major structural features of the mitochondrial genome among iguanian lizards. *Journal of Molecular Evolution* **44**: 660–674.

MARYAN, B., APLIN, K.P. and ADAMS, M. 2007. Two new species of the *Delma tincta* group (Squamata: Pygopodidae) from northwestern Australia. *Records of the Western Australian Museum* **23**: 273–305.

MURPHY, J.C. 2007. *Homalopsid Snakes Evolution in the Mud.* Krieger Publishing Company, Florida.

NG, P.K.L. and KANG, N. 1988. The mud lobster: Thalassina. *Nature Malaysiana* **13**: 28–31.

NG, P.K.L. and SIVASOTHI, N. (eds.). 1999. *A Guide to the Mangroves of Singapore II: Animal Diversity.* Singapore Science Centre, Singapore.

PIANKA, E.R. 1986. *Ecology and natural history of desert lizards: analyses of the ecological niche and community structure.* Princeton University Press, New Jersey.

POSADA, D. 2008. JModelTest: Phylogenetic Model Averaging. *Molecular Biology and Evolution* **25**: 1253–1256.

READ, J.L. 1998. The ecology of sympatric scincid lizards (*Ctenotus*) in arid South Australia. *Australian Journal of Zoology* **46**: 617–629.

SADLIER, R. 1987. Distribution by

habitat of six *Ctenotus* species in SW N.S.W. *Herpetofauna* **17**: 1–4.

SADLIER, R.A. 1993. A range extension for the scincid lizard *Ctenotus angusticeps* of north-western Australia. *Herpetofauna* **23**: 7–8.

SADLIER, R.A., SMITH, S.A., BAUER, A.M. and WHITAKER, A.H. 2004. A new genus and species of live-bearing scincid lizard (Reptilia: Scincidae) from New Caledonia. *Journal of Herpetology* **38**: 320–330.

SEMENIUK, V., KENNEALLY, K.F. and WILSON, P.G. 1978. *Mangroves of Western Australia*. Western Australian Naturalists' Club, Perth.

STARK, R.C. and FOX, S.F. 2000. Use of fluorescent powder to track horned lizards. *Herpetological Review* **31**: 230.

STORR, G.M. 1988. A new *Ctenotus* (Lacertilia: Scincidae) from Western Australia. *Records of the Western Australian Museum* **14**: 138–140.

STORR, G.M., SMITH, L.A. and JOHNSTONE, R.E. 1999. *Lizards of Western Australia. I Skinks*. Revised Edition. Western Australian Museum.

SUBRAMANIAN, A. 1984. Burrowing behaviour and ecology of the crab-eating Indian snake eel *Pisoodonophis boro*. *Environmental Biology of Fishes* **10**: 195–202.

TAYLOR, J.A. 1984. Burrow construction and utilisation by the lizard, *Ctenotus taeniolatus*. *Herpetofauna* **15**: 44–47.

THREATENED SPECIES SCIENTIFIC COMMITTEE. 2008. *Commonwealth Conservation Advice on Ctenotus angusticeps (Airlie Island Ctenotus)*. Department of Sustainability, Environment, Water, Population and Communities. Canberra, A.C.T.

TURPIN, J. and FORD, S. 2011. A second mainland population of Airlie Island Ctenotus, *Ctenotus angusticeps* (Lacertilia: Scincidae) from Port Hedland, Western Australia, with notes on habitat. *Herpetofauna* **41**: 2–6.

TWIGG, L.E., HOW, R.A., HATHERLY, R.L. and DELL, J. 1996. Comparisons of the diet of three sympatric species of *Ctenotus* skinks. *Journal of Herpetology* **30**: 561–566.

VAN VREESWYK, A.M.E., PAYNE, A.L., LEIGHTON, K.A. and HENNIG, P. 2004. Technical Bulletin – An inventory and condition survey of rangelands in Pilbara Region, Western Australia, No 92. Department of Agriculture, Government of Western Australia, Perth, Western Australia.

WILSON, S. and SWAN, G. 2013. *A Complete Guide to Reptiles of Australia*. Fourth Edition. Reed New Holland, Sydney.

NOTES ON THE ECOLOGY AND NATURAL HISTORY OF THE RARELY RECORDED GEKKONID LIZARD *HETERONOTIA BINOEI* IN THE GREAT VICTORIA DESERT OF WESTERN AUSTRALIA

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ABSTRACT

Ecological data on the uncommonly encountered terrestrial gecko *Heteronotia binoei* are presented and discussed. Although *Heteronotia* is widespread in Australia occurring in many different habitats, it is rarely found in semi-pristine desert habitats. *Heteronotia* is composed of a complex of both sexual and asexual populations which may help explain its rarity. Sex ratio is biased towards females. *Heteronotia* exploit burrows of other animals for shelter and daytime retreats. Compared to other species of desert lizards, *Heteronotia* is a dietary generalist with a relatively broad dietary niche. These geckos reproduce in the Austral spring and have fixed clutch sizes of two eggs. Relative clutch mass averaged 9.9%.

INTRODUCTION

Heteronotia binoei is widespread in Australia (Cogger 1992) and like most geckos, *Heteronotia* is nocturnal, but it can often be found in diurnal retreats such as under objects in rubbish tips (the first stop for many herpetologists). However, it is seldom found in semi-pristine outback desert habitats (Pianka 2014).

This gecko is a species complex consisting of both sexual and parthenogenetic populations (Fujita and Moritz 2009, Moritz 1983, 1991a, 1991b, Moritz and Heideman 1993). Asexuality appears to have arisen multiple times: both bisexual and unisexual forms can occur in sympatry (Fujita *et al.* 2007), where they hybridize (Strasburg and Kearney 2005). A population of this gecko in the Pilliga scrub in New South Wales was studied by mark and recapture by Bustard (1968) who found the geckos below bark at the base of dead trees or stumps. He reported data on movements, growth, tail loss and regeneration as well as on diet.

METHODS

During 11 separate expeditions to the Great Victoria Desert (GVD) of Western Australia from 1966 through 2008, my assistants and I spent 41 months (1256 days) in the field primarily during Austral springs collecting and studying lizards (Pianka 1969a,b, 1982, 1986, 1994, 1996; Pianka and Goodyear 2012). Extensive data were gathered at ten major study areas in the GVD (for exact locations, see Pianka 1986 and Pianka and Goodyear 2012) as well as at other non-study sites nearby. Lizards were collected by any means possible using a wide variety of different techniques including turning over rubbish and fallen logs, exhuming, grabbing, shooting, eyeshine, body shine and pit trapping. Out of a total of more than 20,000 lizards, only 66 individual *Heteronotia binoei* were encountered, 13 of which were juveniles. This species was found at 8 of the 10 study areas and might well be present on the two other areas but was not encountered due to small sample sizes.

We recorded air and body temperatures, times of activity, microhabitat, fresh snout-vent length (SVL), tail length, and weight for as many lizards as possible. Stomach contents were identified and prey volumes estimated for all lizards collected. Reproductive condition was also recorded: for males, lengths of testes were measured; for females, egg sizes were measured and numbers were counted, and whether eggs were ovarian or oviductal was noted [some of these data were summarized in appendices in Pianka (1986)]. Niche breadths were calculated using the inverse of Simpson's (1949) index of diversity [$D = 1/ \Sigma p_i^2$] where p_i is the proportion of resource state *i*.

RESULTS

Sex Ratios and Presence of Males. Among the 25 adult individuals collected on the 8 study areas with *Heteronotia*, six males were present at four of the eight areas (B 3 , E 1, N 1, and R 1) but only females were found at the other four study areas (A 6, G 2, L 3, and Y 3) (numbers represent number of individuals of a given sex). Four other females were found on sites with males. Thus overall sex ratio on the eight study areas is 6/25 or 0.24. Samples are too small to argue that no sexual forms were present on the four sites without males. Among 28 other adult specimens collected incidentally on 15 non-study sites, six other males were also found, a sex ratio of 6/28 or 0.214. Combining samples yields a significantly female-biased sex ratio of 12/53 = 0.226.

Habitat and Microhabitats. *Heteronotia* exploit burrows of other animals for shelter and daytime retreats. They are sometimes found while exhuming burrows of *Liopholis* (formerly *Egernia*) *striata*. They also dig their own small burrows off to the sides of larger burrows such

as those dug by monitor lizards or rabbit warrens. Of 66 geckos, all but two were found on desert flats and sandplains, one was caught at the base/slope of a sandridge and another was captured on a sandridge crest. Six individuals were dug up in various burrows mostly those dug by *Liopholis*. Of 24 individuals found active at night, one was at the mouth of such a burrow, two were found emerging at dusk from the mouth of a rabbit warren, two were in hollow termite mounds, one was about 7 cm above ground at the base of a termite mound, one was 60 cm above ground in a rock crevice, nine were out in the open, two were close to spinifex tussocks, two near bushes, and four were in litter beneath Marble Gum trees.

Thermal Relations. Like all nocturnal geckos, *Heteronotia* are thermoconformers, with body temperatures positively correlated with ambient air temperatures (Figure 1). No statistical thermal difference exists between active geckos versus those found in diurnal retreats. Body temperatures of these geckos tend to be slightly above ambient temperature especially when they are cold.

Diet. *Heteronotia* are dietary generalists, consuming a wide variety of arthropods, especially spiders, grasshoppers and crickets (Table 1). Based on these data, dietary niche breadth is 7.72.

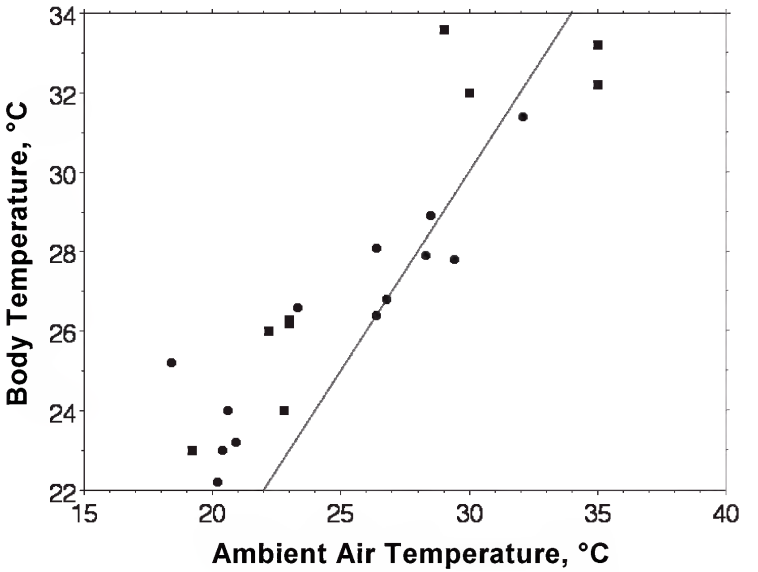

Figure 1. Body temperatures plotted against ambient air temperature for 24 *Heteronotia*. Circles are active geckos at night whereas squares are those in diurnal retreats. The line represents body temperature equal to ambient air temperature.

Table 1. Summary of stomach contents of 66 *Heteronotia.*

	Number	Volume	Proportion
Centipedes	1	0.05	0.020
Spiders	21	0.69	0.282
Scorpions	1	0.01	0.001
Ants	5	0.09	0.037
Wasps	1	0.01	0.004
Locustids	6	0.36	0.147
Thysanurans	2	0.02	0.008
Roaches	1	0.17	0.069
Mantids/Phasmids	2	0.05	0.020
Beetles	6	0.11	0.045
Termites	42	0.13	0.053
Hemipterans	9	0.13	0.053
Lepidopterans	2	0.14	0.057
Larvae	5	0.09	0.037
Other Insects	8	0.14	0.057
Vertebrates	4	0.18	0.074
Vegetation	1	0.04	0.016
Other Unidentified	1	0.05	0.02
Totals	119	2.46	1.00

Reproduction. Ten females had either enlarged yolked ovarian eggs or shelled eggs in their oviducts from September to January. All had clutches of two eggs. Relative clutch mass (egg volume over female fresh body weight) averaged 9.9% for three females with shelled eggs in their oviducts. Average snout vent length (SVL) of gravid females is 44.1 mm. Average SVL of 12 adult males is 46 mm.

DISCUSSION

When I assembled data for my 1986 book, I was puzzled by the rarity of *Heteronotia* — this species was present on 8 of my 10 study areas but only as singletons at 5 sites and only in very small numbers at other sites where this gecko was present. Only 19 geckos were collected at ten study areas over the course of two years of field work. I wondered how it could be a dietary generalist and occur at most sites but still be so uncommon. Craig Moritz's discovery of parthenogenetic forms offered an answer to this dilemma: an all female unisexual does not require males and females could persist at near vanishingly low densities. I remain baffled about how this rare gecko manages to disperse so effectively across the vast desert landscape.

Extensive pit trapping from 1989 to 2008 (over 62,000 pit trap

days) at 3 study sites yielded only 22 additional specimens, confirming the rarity of *Heteronotia*.

ACKNOWLEDGEMENTS

For companionship and assistance in the field, I thank R. Allen, D. Beaton, K. Beaton, D. Bennett, H. L. Dunlap, R. Dybdahl, A. Frank, W. F. Giles, S. E. Goodyear, W. B. Jennings, D. R. King, F. Odendaal, D. J. Pearson, M. Peterson, G. A. Pianka, C. Roscoe, W. Saunders, K. Smith, L. A. Smith, and G. G. Thompson. Others who contributed in various ways to this research include J. Anderson, K. Aplin, S. Argus, J. Banning, A. A. Burbidge, M. A. Cowan, H. Gordon, M. Grenadier, R. A. How, V. Johnson Dennison, G. A. Kaufman, I. Kealley, A. R. Main, B. Maryan, N. Scade, and G. M. Storr. Stomach contents were identified by M. E. Egan, S. E. Goodyear, C. Harp, S. McMahon, T. D. Schultz, and V. Stringer. Undergraduate research assistants assisted with dissections and laboratory analyses. I thank editor John Dell for many suggestions that greatly improved this manuscript.

This research was supported out of my own pocket and by grants from the National Geographic Society, the John Simon Guggenheim Memorial Foundation, a senior Fulbright Research Scholarship, the Australian-American Educational Foundation, the University Research Institute of the Graduate School at The University of Texas at Austin, the Denton A. Cooley Centennial Professorship in Zoology at The University of Texas at Austin, the US National Science Foundation, and the US National Aeronautics and Space Administration. I also thank staffs of the Department of Zoology at the University of Western Australia, the Western Australian Museum, the Department of Conservation and Land Management (CALM) in Kalgoorlie, and the Western Australian Department of Environment and Conservation (DEC). Lizards were collected under permits issued by CALM and DEC with the approval of appropriate animal ethics committees in Australia and the University of Texas. Specimens are housed in the Los Angeles County Museum of Natural History and the Western Australian Museum.

REFERENCES

BUSTARD, H.R. 1968. The ecology of the Australian gecko *Heteronotia binoei* in northern New South Wales. *Journal of Zoology* 156: 483–497.

COGGER, H.G. 1992. *Reptiles and Amphibians of Australia, 5th* ed. Reed Books. 775 pp.

FUJITA, M.K. and C. MORITZ. 2009. Origin and Evolution of Parthenogenetic Genomes in Lizards: Current State and Future Directions. *Cytogenetics and Genome Research* 127: 261–272

FUJITA, M. K., J. L. BOORE, and C.

MORITZ. 2007. Multiple Origins and Rapid Evolution of Duplicated Mitochondrial Genes in Parthenogenetic Geckos (*Heteronotia binoei*; Squamata, Gekkonidae). *Molecular Biology and Evolution* 24: 2775–2786.

MORITZ C. 1983. Parthenogenesis in the Endemic Australian Lizard *Heteronotia binoei* (Gekkonidae). *Science* 220: 735–737.

MORITZ, C. 1991a. The origin and evolution of parthenogenesis in *Heteronotia binoei* (Gekkonidae): Evidence for recent and localized origins of widespread clones. *Genetics* 129: 211–219

MORITZ, C. 1991b. Evolutionary dynamics of mitochondrial DNA duplications in parthenogenetic geckos, *Heteronotia binoei. Genetics* 129: 221–230.

MORITZ, C. and A. HEIDEMAN. 1993. The orgin and evolution of parthenogenesis in *Heteronotia binoei* (Gekkonidae): reciprocal origins and diverse mitochondrial DNA in western populations. *Systematic Biology* 42 (3): 293–306

PIANKA, E. R. 1969a. Habitat specificity, speciation, and species density in Australian desert lizards. *Ecology* 50: 498–502.

PIANKA, E. R. 1969b. Sympatry of desert lizards (*Ctenotus*) in Western Australia. *Ecology* 50: 1012–1030.

PIANKA, E. R. 1982. Observations on the ecology of *Varanus* in the Great Victoria desert. *Western Australian Naturalist* 15: 37–44.

PIANKA, E. R. 1986. *Ecology and Natural History of Desert Lizards. Analyses of the Ecological Niche and Community Structure.* Princeton University Press, Princeton, New Jersey.

PIANKA, E. R. 1994. Comparative ecology of *Varanus* in the Great Victoria desert. *Australian Journal of Ecology* 19: 395–408.

PIANKA, E. R. 1996. Long-term changes in Lizard Assemblages in the Great Victoria Desert: Dynamic Habitat Mosaics in Response to Wildfires. Chapter 8 (pp. 191–215) in M. L. Cody and J. A. Smallwood (eds.) *Long-term studies of vertebrate communities.* Academic Press.

PIANKA, E. R. 2011. Notes on the ecology of some uncommon skinks in the Great Victoria Desert. *Western Australian Naturalist* 28: 50–60.

PIANKA, E. R. 2014. Rarity in Australian Desert Lizards. *Austral Ecology* 39, in press.

PIANKA, E. R. and S. E. GOODYEAR. 2012. Lizard responses to wildfire in arid interior Australia: Long-term experimental data and commonalities with other studies. *Austral Ecology* 37: 1–11.

SIMPSON, E. H. 1949. Measurement of diversity. *Nature,* 163, 688.

STRASBURG, J. L. and M. KEARNEY 2005. Phylogeography of sexual *Heteronotia binoei* (Gekkonidae) in the Australian arid zone: climatic cycling and repetitive hybridization. *Molecular Ecology* 14: 2755–2772.

AN AUTUMN SURVEY OF THE VASCULAR FLORA, BIRDS, FUNGI, MYXOMYCETES AND LICHENS OF BALADJIE LAKE NATURE RESERVE AND BALADJIE ROCK

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ABSTRACT

In April 2009 the Western Australian Naturalists' Club conducted a biological survey at the Baladjie Lake Nature Reserve and at Baladjie Rock, on the western edge of the Great Western Woodlands near the town of Bullfinch. 97 specimens of lichens (including *Parmeliopsis macrospora*, a Listed Priority 3 species), 15 fungi, 13 vascular flora and six myxomycetes (slime moulds) were collected in this survey and deposited in the Western Australian Herbarium. Twenty-five species of birds were also recorded in the area. An updated inventory of all flora comprising 170 species and lichen records (including those made in the current survey) was compiled for the Baladjie area from herbarium records.

INTRODUCTION

The 2009 Easter Excursion of the Western Australian Naturalists' Club (WANATS) involved 23 club members who camped near Baladjie Rock in the Shire of Yilgarn for seven days (April 8–14). The purpose of the excursion was to conduct a survey of the vascular flora, fungi, lichens and birds at the request of the then Department of Environment and Conservation (DEC).

The Baladjie Lakes Nature Reserve (C42720) encompasses about 8,916.34ha adjacent to the Baladjie Rock Water Reserve and is located about 16km north-west of the small town of Bullfinch in the Shire of Westonia. It straddles the border between the Avon Wheatbelt and Coolgardie IBRA Bioregions and is thus part of the Great Western Woodlands which form the largest area of temperate climate woodlands in the world. The Great Western Woodlands (about 160,000 km^2) are also remarkable on a global scale due to their high biodiversity and largely pristine vegetation and because woodland formations elsewhere do not inhabit areas with such dry climates and nutrient poor soils.

The Baladjie Lakes and Baladjie Rock are located within the Yilgarn Block, a stable Archaean Craton that consists of belts of banded gneiss, ironstone and layered sedimentary, volcanic and intrusive rocks (Chin and Smith 1983). The gently undulating landscape of this area comprises lateritic, duricrusted uplands and sandplains (at an elevation of about 400m) dissected by broad paleodrainage channels (now chains of shallow salt lakes). In places where the landscape above has eroded away to a lower plain, there are often residual monadnocks such as Elachbutting Hill (elevation 407m) and Baladjie Rock (elevation 377m) that are emergent from this plain.

Prior to this excursion, the local flora was known from only 93 vascular plant collections in the Western Australian Herbarium (1998–). The Department of Environment and Conservation has also previously compiled a list of 97 taxa for the reserve (Ben Lullfitz, pers. comm.) but there were no fine scale vegetation maps available for the area.

METHODS

To sample the vascular flora, three permanent 30m x 30m quadrats (Table 1; Figure 1) were set out in eucalypt woodland using the system of Keighery (1994). Galvanised fence droppers were placed at the four corners of each quadrat. A marker peg was also placed on a nearby track to assist in the relocation of the quadrats. Each quadrat was photographed from the north east corner. All taxa of trees, shrubs, herbs, grasses, sedges, and lichens in the quadrats were recorded and identified. Additional opportunistic collections and records of vascular plants, fungi and lichens were also made outside the quadrats.

Fungal fruiting bodies were collected opportunistically and placed in paper bags. The substrates and vegetation associated with these locations were noted. In the laboratory, the collections were identified by Elaine Davison using standard keys (Cunningham 1979, Grgurinovic 1997). Spores and capillitium were mounted in lactophenol cotton blue and examined at x 1000 magnification. All collections have been deposited in PERTH.

Myxomycetes were grown in moist chambers (Stephenson and Stempen 1994) on bark from *Acacia* sp. narrow phyllode (B.R. Maslin 7831), *Eucalyptus petraea*, collected close to the quadrats. The chambers were observed at frequent intervals and any myxomycetes that developed were mounted on slides and identified using standard keys

Table 1. Location of flora sampling quadrats at Baladjie Nature Reserve

Quadrat	Location
BR1	30° 57' 07.0"S, 118° 52' 31.1"E
BR2	30° 56' 57.7"S, 118° 52' 50.7"E
BR3	30° 52' 51.8"S, 118° 55' 08.3"E

Figure 1. Quadrat locations at Baladjie Lake Nature Reserve and Baladjie Rock.

(Mitchell 2003, Neubert *et al.* 2000). All collections have been deposited in PERTH.

Updated inventories of all vascular flora and lichens known from Baladjie Lakes Nature Reserve and Baladjie Rock were compiled from records of specimens held at PERTH (WA Herbarium 1998–) and records from this survey. It is unknown if there have been previous fungi and slime mould (myxomycete) collections in the area as records for these groups are not readily available from WA Herbarium (1998).

A list of birds that were sighted or heard by all members of the excursion was compiled during the survey. This included all birds identified near the three flora sampling quadrats at specific times during the flora survey (Table 2).

RESULTS

1. Vascular Flora and Vegetation

The current survey found samphires and shrublands adjacent to the Baladjie Lakes, and mallee and woodlands further from the lakes. The mallee *Eucalyptus petraea* (Granite Rock Box) formed stands near the base of Baladjie Rock and *Eucalyptus loxophleba* subsp. *lissophloia* (the smooth bark form of the York Gum) was also nearby. *Eucalyptus kochii* subsp. *plenissima* (Trayning Mallee) grew further away from the rock towards the salt lakes. *Eucalyptus salmonophloia* (Salmon Gum) and *Eucalyptus salubris* (Gimlet) were the larger trees of the area.

Table 2. Bird observation locations/ times at or near flora quadrats

Nearest quadrat	Date and time of records
BR1	April 11, 10:30am to 11:15am
BR2	April 11, 3:00pm to 3:45pm
BR3	April 12, 10:00am to 10:45am

The understorey layers of the mallee and woodlands were dominated by *Acacia* spp., including *Acacia* sp. narrow phyllode (B.R. Maslin 7831) (the Northern Jam Wattle) and *Acacia tetragonophylla* (Kurarra). Also common were *Bursaria occidentalis*, *Eremophila clarkei* (Turpentine Bush), *Eremophila drummondii*, *Eremophila ionantha* (Violet-flowered Eremophila), *Eremophila scoparia* (Broom Bush), *Leptospermum fastigiatum*, *Leptospermum macgillivrayi*, *Olearia dampieri* subsp. *eremicola*, *Olearia pimeleoides* (Pimelea Daisybush), *Olearia muelleri* (Goldfields Daisy) and *Pittosporum angustifolium*.

All of the vegetation was generally in very good or excellent condition with little disturbance except occasional signs of rabbit activity.

Forty-six specimens of vascular flora were recorded in this survey, identified by the author and Gilbert Marsh and 13 specimens were deposited in PERTH (WA Herbarium 1998–). The taxa identified in the field and deposited in the herbarium

are listed with previous herbarium records from this location in Appendix 1.

The vegetation sampled in the quadrats of the current survey is briefly described below in terms of the dominant (greater than 2 % cover) taxa in each layer.

BR-1: Mid-dense *Eucalyptus loxophleba* subsp. *lissophloia* mallee (40% cover); over *Calycopeplus paucifolius* tall, open shrubs (>2m, 5% cover); *Acacia* sp. narrow phyllode (B.R. Maslin 7831) and other low, open shrubs; and sparse annual grasses. Common associates of this vegetation are listed below.

Shrubs <2m: *Acacia tetragonophylla, Eremophila decipiens, Eremophila drummondii, Leptospermum fastigiatum, Olearia dampieri* subsp. *eremicola, Olearia muelleri, Olearia pimeleoides, Rhagodia drummondii, Santalum acuminatum* and *Solanum nummularium.*

Grasses: *Aristida contorta, Austrostipa trichophylla.*

Perennial herbs: *Dianella revoluta.*

Annual herbs: *Waitzia acuminata* var. *acuminata* (dead).

Hemi-parasite: *Amyema miquelii* (on *Eucalyptus loxophleba* subsp. *lissophloia*).

This quadrat was at the base of Baladjie Rock to the north of the camping area. It was a poorly drained flat with orange, granitic, gravelly soil and 50% bare ground. *Leptospermum fastigiatum* formed dense thickets closer to Baladjie Rock.

BR-2: Open *Eucalyptus kochii* subsp. *plenissima* mallee (25% cover) over *Exocarpos aphyllus-Dodonaea viscosa* subsp. *angustissima* tall, open shrubs (>2m, 10% cover); over low open *Senna artemisioides* subsp. *filifolia* shrubs (<2m, 5% cover); and other low open shrubs including *Olearia muelleri* and *Rhagodia drummondii* (<1m); and sparse *Austrostipa elegantissima* perennial grass (5 % cover).

Associates of this vegetation are listed below.

Shrubs <2m: *Acacia* sp. narrow phyllode (B.R. Maslin 7831) *Atriplex nummularia, Callitris columellaris, Eremophila oppositifolia, Maireana diffusa, Maireana georgei, Olearia muelleri, Ptilotus nobilis* subsp. *nobilis, Ptilotus obovatus* and *Solanum hoplopetalum*

Perennial herbs: *Thysanotus manglesianus* (dead).

Annual herbs: *Podolepis capillaris* (dead).

Hemi-parasite: *Amyema miquelii* on (*Eucalyptus kochii* subsp. *plenissima*).

This quadrat was at the north end of Baladjie Rock (close to a small lobe of the salt lake) on orange sand with a 50% litter cover.

BR-3: *Eucalyptus salubris* low open woodland of (<10m, 10% cover); over tall *Eremophila scoparia* and *Acacia* sp. narrow phyllode (B.R. Maslin 7831) shrubs (>2m, 15% cover); over *Atriplex nummularia* low open shrubs (<2m, 5% cover).

Associates of this vegetation are listed below.

Shrubs <2m: *Eremophila clarkei, Eremophila ionantha, Eremophila oppositifolia, Eremophila scoparia, Exocarpos aphyllus, Scaevola spinescens, Senna artemisioides* subsp. *filifolia* and *Senna chatelainiana*

Shrubs <0.5m: ?*Dissocarpus paradoxus, Maireana* sp., *Ptilotus nobilis* subsp. *nobilis* and *Ptilotus obovatus*

Grasses: *Austrostipa pycnostachya*

This quadrat was approximately 11.5 km NNE of Baladjie Rock just west of the track running up to the Mt Jackson Road alongside Lake Baladjie. The soil was poorly-drained, lichen-covered, orange clay-sand, with about 5% litter cover.

2. Lichens

Ninety-seven lichen specimens (from 13 families and at least 21 genera and 36 species) were collected (Appendix 2). These collections were identified by Ray Cranfield of DPaW (Manjimup) and all specimens were deposited in PERTH.

3. Fungi and Myxomycetes (Slime Moulds)

Thirteen collections of fungi (from five families, six genera and at 11 species) were made (Appendix 3). All were taxa with persistent fruiting bodies. Nine (*Geastrum* spp., *Podaxis pistillaris, Pisolithus* sp., *Tulostoma* spp.) were puffballs or puffball-like species and occurred on the ground. The other two, *Pycnoporus coccineus* and *Gloeophyllum* sp., were brackets growing on dead wood.

In addition to these macrofungi, bark incubated in moist chambers yielded six species of Myxomycetes (Appendix 4). These include *Arcyria pausiaca*, an uncommon species worldwide, which has been found several times on bark from arid and semi-arid areas in Australia (Davison and Davison, unpublished).

These groups were identified by Elaine Davison (Curtin University) and all collections were deposited in PERTH.

4. Avifauna

Twenty-five bird species were noted in the general Baladjie Rock/ Baladjie Lakes Nature Reserve area and adjacent to the three flora sampling quadrats (Appendix 5).

DISCUSSION

The flora survey was conducted at a low intensity during dry, autumn weather. However, although there were no vascular flora taxa of listed conservation significance found in this survey, 31 taxa not previously known from the area (WA Herbarium, 1998–) were collected in this survey. It is recommended that additional flora surveys are carried out in spring at Baladjie to survey the annuals and geophytes. The playa vegetation also appears to be worth further investigation as a Priority 1 species (*Tecticornia flabelliformis)*

is known from the area (WA Herbarium, 1998–). Classifying and mapping the fine-scale vegetation assemblages in the area could also provide useful information for the management of the area.

The low number of birds recorded in this survey probably also reflected the warm to hot, dry weather conditions at the time of survey and the low intensity of the survey.

The lichen collections made in this survey were the first lichens recorded at Baladjie since 1971, when Prof. A. R Main (1919–2009), a long-term member and a patron of the Western Australian Naturalists' Club, collected three taxa at Baladjie Rock and lodged them in the WA Herbarium collection. None of the taxa collected by Prof. Main were re-collected in the current survey. One lichen species (*Parmeliopsis macrospora*) that was collected in the current survey is listed as a Priority 3 taxon by DPaW (Western Australian Herbarium 1998–). Seven of the species collected in the current survey (including *Parmeliopsis macrospora*) were first records for the Coolgardie and Avon Wheatbelt IBRA Bioregions.

The fungi and slime moulds collected in this survey appear to be the first collections of these groups from Baladjie Lakes Nature Reserve and Baladjie Rock. to be deposited at the WA Herbarium. The macrofungi that occur in arid areas of Australia are not well known. Some species that were collected in this survey (e.g. *Podaxis pistillaris*) are conspicuous and widespread (Grey and Grey 2001), but the small stalked puffballs (*Tulostoma* spp.) and earthstars (*Geastrum* spp.) are easily overlooked. These latter genera contain many species that can only be separated by microscopic examination. The species found at Baladjie Lake Nature Reserve and Baladjie Rock are similar to those from arid areas in other parts of Western Australia and in the Northern Territory (Davison, unpublished).

The fungi that occur in arid areas fill the same ecological niches as those that occur in more mesic environments. Some, such as *Pisolithus* are mycorrhyzal with shrubs and trees. Decomposers, such as *Pycnoporus coccineus* and *Gloeophyllum* are important for recycling cellulose and lignin. It is only when weather conditions are suitable that they produce macroscopic fruiting bodies, and this is less frequent at Baladjie than in higher rainfall areas.

From this survey, lichens and fungi appear to be significant components of the biodiversity at Baladjie. Further surveys of these poorly known groups in other areas of the Great Western Woodlands may contribute insights into the ecology of this poorly known area.

ACKNOWLEDGEMENTS

WA Naturalist's Club members who participated in this Easter

Excursion survey were Daphne Edinger, John and Ruth Luyer (who collated the bird data), Elaine and Peter Davison (who led the collection of the fungi and slime moulds), Penny Hussey (who led the collection of the lichens), John Abbott, Margaret and Alec Brimms, Yvonne and Peter Broome, Margaret Larke, Gilbert Marsh, Lyn Myles, Graeme Rundle, Marlene and Bob Willis, Joan and Rob Sharp, Jolande Keeble, Yvonne and Kevin Coate and Rob and Maureen Skeet. Rohan Swan developed an electronic draft of this paper. Ben Lullfitz (Conservation Officer, DEC Yilgarn) provided information and assistance in the planning of this trip. The paper was edited by Cate Tauss.

REFERENCES

CHIN, R.J. and SMITH, R.A. 1983. *1:250,000 Geological Series, Jackson, SH/50.* Geological Survey of Western Australia.

CUNNINGHAM, G. H. 1979. *The Gasteromycetes of Australia and New Zealand.* J Cramer, FL-9490 Vaduz.

GREY, P. and GREY, E. 2001. *Fungi Down Under, the Fungimap Guide to Australian Fungi.* Fungimap, c/o Royal Botanic Gardens Melbourne.

GRGURINOVIC, C. A. 1997. *Larger Fungi of South Australia.* The Botanic Gardens of Adelaide and State Herbarium and the Flora and Fauna of South Australia. Handbooks Committee, Adelaide.

KEIGHERY, B.J. 1994. *Bushland plant survey. A guide to plant community survey for the community.* Wildflower Society of WA (Inc).

MITCHELL, D.W. 2003. Myxomycete keys. CD-ROM privately published by the author.

NEUBERT., NOWOTNY, W. and BAUMANN, K. 2000. *Die Myxomyceten.* Karlheinz Baumann Verlag, Gomaringen.

STEPHENSON, S. L. and STEMPEN, H. 1994. *Myxomycetes: a Handbook of Slime Molds.* Timber Press, Inc., Oregon, USA

WA HERBARIUM, 1998– FloraBase. Department of Parks and Wildlife, Western Australia. http://florabase.calm.wa.gov.au/ Accessed January, 2013.

Appendix 1. The vascular flora recorded at Baladjie Lakes Nature Reserve and Baladjie Rock in April 2009 and all WA Herbarium (1998–) records from these locations.

FAMILY	TAXON	FloraBase prior records	BR1	BR2	BR3	Opportunistic record, this survey
Aizoaceae	*Gunniopsis intermedia* Diels	*				
Aizoaceae	*Gunniopsis quadrifida (F.Muell.) Pax*	*				
Amaranthaceae	*Ptilotus nobilis* (Lindl.) F.Muell. subsp. *nobilis*	*		*	*	
Amaranthaceae	*Ptilotus obovatus* (Gaudich.) F.Muell.	*		*	*	
Asparagaceae	*Chamaexeros fimbriata* (F.Muell.) Benth.	*				
Asparagaceae	*Thysanotus manglesianus* Kunth	*		*		
Asteraceae	*Angianthus* aff. *micropodioides*	*				
Asteraceae	*Angianthus prostratus* P.S.Short	*				
Asteraceae	*Angianthus tomentosus* J.C.Wendl.	*				
Asteraceae	*Erymophyllum ramosum* (A. Gray) Paul G. Wilson subsp. *ramosum*	*				
Asteraceae	*Cephalipterum drummondii* A.Gray	*				
Asteraceae	*Cratystylis subspinescens* S.Moore	*				
Asteraceae	*Gilberta tenuifolia* Turcz.	*				
Asteraceae	*Gnephosis acicularis* Benth.	*				
Asteraceae	*Goodenia quasilibera* Carolin	*				
Asteraceae	*Gnephosis tenuissima* Cass.	*				
Asteraceae	*Olearia dampieri* subsp. *eremicola* (Diels) Lander ms		*			
Asteraceae	*Olearia muelleri* (Sond.) Benth.	*	*	*		
Asteraceae	*Olearia pimeleoides* (DC.) Benth.	*	*			
Asteraceae	*Podolepis capillaris* (Steetz) Diels	*		*		
Asteraceae	*Podotheca pritzelii* P.S.Short P3	*				
Asteraceae	*Senecio pinnatifolius* A.Rich.	*				
Asteraceae	*Waitzia acuminata* Steetz var. *acuminata*		*			
Brassicaceae	*Stenopetalum salicola* Keighery	*				
Campanulaceae	*Isotoma petraea* F.Muell.	*				
Campanulaceae	*Lobelia winfridae* Diels	*				
Centrolepidaceae	*Centrolepis cephaloformis* Reader subsp. *cephaloformis*	*				
Centrolepidaceae	*Centrolepis eremica* D.A.Cooke	*				
Centrolepidaceae	*Centrolepis polygyna* (R.Br.) Hieron.	*				
Chenopodiaceae	*Atriplex nana* Parr-Smith	*				
Chenopodiaceae	*Atriplex nummularia* Aellen subsp. *spathulata* Aellen	*			*	

FAMILY	TAXON	FloraBase prior records	BR1	BR2	BR3	Opportunistic record, this survey
Chenopodiaceae	*Atriplex stipitata* Benth.	*				
Chenopodiaceae	*Atriplex nummularia* Lindl.			*	*	
Chenopodiaceae	? *Dissocarpus paradoxus* (R.Br.) Ulbr.				*	
Chenopodiaceae	*Enchylaena tomentosa* R.Br. var. *tomentosa*	*				
Chenopodiaceae	*Maireana amoena* (Diels) Paul G.Wilson	*				
Chenopodiaceae	*Maireana diffusa* Paul G.Wilson			*		
Chenopodiaceae	*Maireana georgei* (Diels) Paul G.Wilson			*		
Chenopodiaceae	*Maireana* sp.				*	
Chenopodiaceae	*Maireana thesioides* (C.A.Gardner) Paul G.Wilson	*				
Chenopodiaceae	*Rhagodia drummondii* Moq.		*	*		
Chenopodiaceae	*Rhagodia preissii* Moq. subsp. *preissii*	*				
Chenopodiaceae	*Roycea ?divaricata* Paul G.Wilson	*				
Chenopodiaceae	*Sarcocornia blackiana* (Ulbr.) A.J.Scott	*				
Chenopodiaceae	*Sclerolaena diacantha* (Nees) Benth.	*				
Chenopodiaceae	*Sclerolaena eurotioides* (F.Muell.) A.J.Scott	*				
Chenopodiaceae	*Sclerolaena fusiformis* Paul G.Wilson	*				
Chenopodiaceae	*Sclerolaena parviflora* (R.H.Anderson) A.J.Scott	*				
Chenopodiaceae	*Tecticornia disarticulata* (PaulG.Wilson) K.A.Sheph. & Paul G.Wilson	*				
Chenopodiaceae	*Tecticornia flabelliformis* (Paul G.Wilson) K.A.Sheph. & Paul G.Wilson	*				
Chenopodiaceae	*Tecticornia halocnemoides* (Nees) K.A.Sheph. & Paul G.Wilson	*				
Chenopodiaceae	*Tecticornia pergranulata* (J.M.Black) K.A.Sheph. & Paul G.Wilson subsp. *pergranulata*	*				
Chenopodiaceae	*Tecticornia* sp. Dennys Crossing (K.A. Shepherd & J. English KS 552) pn	*				
Cupressaceae	*Callitris columellaris* F.Muell.	*		*		
Ericaceae	*Leucopogon* sp. Kau Rock (M.A. Burgman 1126) PN	*				
Euphorbiaceae	*Calycopeplus paucifolius* (Klotzsch) Baill.	*	*			
Euphorbiaceae	*Ricinocarpos velutinus* F.Muell	*				
Fabaceae	*Acacia* sp. narrow phyllode (B.R. Maslin 7831)		*	*	*	
Fabaceae	*Acacia coolgardiensis* Maiden	*				
Fabaceae	*Acacia leptopetala* Benth.	*				
Fabaceae	*Acacia ligulata* Benth.	*				

FAMILY	TAXON	FloraBase prior records	BR1	BR2	BR3	Opportunistic record, this survey
Fabaceae	*Acacia* sp. narrow phyllode (B.R. Maslin 7831) PN	*				
Fabaceae	*Acacia tetragonophylla* F.Muell.	*	*			
Fabaceae	*Jacksonia arida* Chappill	*				
Fabaceae	*Senna artimisioides* subsp. *filifolia*			*	*	
Fabaceae	*Senna glutinosa* subsp. *chatelainiana* (Gaudich.) Randell				*	
Frankeniaceae	*Frankenia cinerea /puncata*	*				
Frankeniaceae	*Frankenia cinerea* A.DC.	*				
Frankeniaceae	*Frankenia* sp.	*				
Frankeniaceae	*Frankenia tetrapetala* Labill.	*				
Goodeniaceae	*Scaevola spinescens* R. Br.			*	*	
Goodeniaceae	*Goodenia quasilibera* Carolin	*				
Goodeniaceae	*Velleia rosea* S.Moore	*				
Hemerocallidaceae	*Dianella revoluta* R. Br		*			
Lamiaceae	*Prostanthera semiteres* Conn subsp. *semiteres*	*				
Lamiaceae	*Westringia rigida* R.Br.	*				
Loranthaceae	*Amyema miquelii* (Lehm. ex Miq.) Tiegh		*	*		
Loranthaceae	*Amyema benthamii* (Blakely) Danser		*	*		
Loranthaceae	*Lysiana casuarinae* {Miq.} Tiegh.	*				*
Malvaceae	*Brachychiton gregorii* F.Muell.	*				
Myrtaceae	*Darwinia diosmoides* (DC.) Benth.	*				
Myrtaceae	*Eucalyptus brachycorys* Blakely	*				
Myrtaceae	*Eucalyptus corrugata* Luehm.	*				
Myrtaceae	*Eucalyptus kochii* subsp. *plenissima*			*		
Myrtaceae	*Eucalyptus loxophleba* subsp. *lissophloia*		*			
Myrtaceae	*Eucalyptus petraea* D.J.Carr & S.G.M.Carr	*				*
Myrtaceae	*Eucalyptus salicola* Brooker	*				
Myrtaceae	*Eucalyptus salubris* F.Muell.				*	
Myrtaceae	*Kunzea pulchella* (Lindl).	*				
Myrtaceae	*Leptospermum fastigiatum*		*			
Myrtaceae	*Leptospermum macgillivrayi* Joy Thomps.					*
Myrtaceae	*Melaleuca hamata* Fielding & Gardner					
Myrtaceae	*Melaleuca lateriflora* Benth.	*				
Myrtaceae	*Melaleuca macronychia* Turcz.	*				
Myrtaceae	*Melaleuca vinnula* Craven & Lepschi	*				
Myrtaceae	*Verticordia halophila* A.S.George	*				
Polygalaceae	*Comesperma integerrimum* Endl.	*				

FAMILY	TAXON	FloraBase prior records	BR1	BR2	BR3	Opportunistic record, this survey
Portulacaceae	*Calandrinia granulifera* Benth	*				
Pittosporaceae	*Bursaria occidentalis* E.M.Benn.					*
Pittosporaceae	*Pittosporum angustifolium* Lodd.	*				
Poaceae	*Aristida contorta* F.Muell.	*	*			
Poaceae	*Austrostipa elegantissima* (Labill.) S.W.L.Jacobs & J.Everett		*	*		
Poaceae	*Austrostipa hemipogon* (Benth.) S.W.L.Jacobs & J.Everett	*				
Poaceae	*Austrostipa pycnostachya* (Benth.) S.W.L.Jacobs & J.Everett.				*	
Poaceae	*Austrostipa* sp.	*				
Poaceae	*Austrostipa trichophylla* (Benth.) S.W.L.Jacobs & J.Everett		*			
Poaceae	*Spartochloa scirpoidea* (Steud.) C.E.Hubb.	*				
Proteaceae	*Grevillea levis* Olde & Marriott	*				
Proteaceae	*Grevillea sarissa* S.Moore subsp. *sarissa*	*				
Proteaceae	*Hakea preissii* Meisn.	*				
Proteaceae	*Hakea recurva* Meisn. subsp. *recurva*	*				
Rutaceae	*Phebalium canaliculatum* (F.Muell. & Tate) J.H.Willis	*				
Santalaceae	*Santalum acuminatum* (R.Br.) A.DC.		*			
Santalaceae	*Exocarpos aphyllus* R.Br.			*	*	
Sapindaceae	*Dodonaea viscosa* (DC.) J.G.West subsp. *angustissima* (DC.) J.G.West	*		*		
Scrophulariaceae	*Eremophila decipiens* Ostenf.	*	*			
Scrophulariaceae	*Eremophila drummondii* F.Muell.		*			
Scrophulariaceae	*Eremophila miniata* C.A.Gardner	*				
Scrophulariaceae	*Eremophila oppositifolia* R.Br.	*		*	*	
Scrophulariaceae	*Eremophila scoparia* (R.Br.) F.Muell.				*	
Scrophulariaceae	*Eremophila clarkei* Oldfield & F.Muell.				*	
Scrophulariaceae	*Eremophila ionantha* Diels.				*	
Scrophulariaceae	*Eremophila ?ionantha x scoparia*				*	
Solanaceae	*Solanum hoplopetalum* Bitter & Summerh.			*		
Solanaceae	*Solanum nummularium* S.Moore.		*			

Appendix 2. The lichens of Baladjie Lakes Nature Reserve and Baladjie Rock.

FAMILY	TAXON	Prior records	BR1	BR2	BR3	First record in A W & COOL Bioregions #
Acarosporaceae	*Sarcogyne regularis* Körb.				*	
Candelariaceae	*Candelariella xanthostigmoides* (Müll. Arg.) R.W. Rogers		*			
Cladoniaceae	*Heterodea beaugleholei* Filson				*	
Cladoniaceae	*Heterodea muelleri* (Hampe) Nyl.		*			
Collemataceae	*Collema coccophorum* Tuck.		*			
	Genus sp. (D. Edinger BR1 13b)		*			
	Genus sp. (D. Edinger BR1 17d)		*			
	Genus sp. (D. Edinger BR2 16a)			*		
Lecideaceae	*Lecidea capensis* Zahlbr.		*			*
Parmeliaceae	*Canoparmelia pruinata* (Müll. Arg.) Elix & J. Johnst.			*		
Parmeliaceae	*Flavoparmelia diffractaica* Elix & J. Johnst.			*		
Parmeliaceae	*Flavoparmelia rutidota* (Hook. f. & Taylor) Hale		*		*	
Parmeliaceae	*Imshaugia subarida* (Elix) Elix		*			*
Parmeliaceae	*Parmeliopsis macrospora* (Elix & J.Johnst.) Elix				*	
Parmeliaceae	*Parmeliopsis macrospora* (Elix & J.Johnst.) Elix		*	*		*
Parmeliaceae	*Xanthoparmelia constipata* (Kurok. & Filson) Elix & J. Johnst.	AR Main 1971				
Parmeliaceae	*Xanthoparmelia flindersiana* (Kurok. & Filson) Elix & J. Johnst.	AR Main 1971				
Parmeliaceae	*Xanthoparmelia luteonotata* (J.Steiner) O.Blanco et al					
Parmeliaceae	*Xanthoparmelia reptans* (Kurok.) Elix & J. Johnst.		*	*	*	
Parmeliaceae	*Xanthoparmelia semiviridis* (Nyl.) O.Blanco et al.			*		
Parmeliaceae	*Xanthoparmelia taractica* (Kremp.) Hale		*	*	*	
Parmeliaceae	*Xanthoparmelia terrestris* (Kurok. & Filson) Elix & J. Johnst.		*	*	*	
Parmeliaceae	*Xanthoparmelia verrucella* (Essl.) O.Blanco et al.			*		
Peltulaceae	*Peltula sp. Edinger, D. BR1 4b*		*			
Physciaceae	*Buellia dissa* (Stirt.) Zahlbr.		*			*

FAMILY	TAXON	Prior records	BR1	BR2	BR3	First record in A W & COOL Bioregions #
Physciaceae	*Buellia georgei* Trinkaus, H. Maryrhofer & Elix		*			*
Physciaceae	*Buellia* sp. (D. Edinger BR-3 10A)				*	
Physciaceae	*Buellia* sp. (D. Edinger BR-1 17e)		*			
Psoraceae	*Psora crenata* (Taylor) Reinke		*	*		*
Psoraceae	*Psora crystallifera* (Taylor) Müll. Arg.		*	*	*	
Psoraceae	*Psora decipiens* (Hedw.) Hoffm.			*	*	
Psoraceae	? *Pyrenopsis* sp. (D. Edinger, BRO 3)				*	
Psoraceae	*Pyrenopsis sp. Edinger, D. Coll No: BRO 3*			*		
Siphulaceae	*Siphula coriacea* Nyl.	AR Main 1971	*	*	*	
Teloschistaceae	*Caloplaca kaernefeltii* S.Y.Kondr., Elix & A.Thell				*	
Teloschistaceae	*Caloplaca* sp. (D. Edinger BRO-1)		*			
Teloschistaceae	*Fulgensia cranfieldii* S.Y. Kondr. & Kärnefelt		*			
Teloschistaceae	*Teloschistes sieberianus* (Laurer) Hillmann				*	
Teloschistaceae	*Xanthoria elixii* S.Y.Kondr. & Karnefelt			*		
Thelotremataceae	*Diploschistes conceptionis* Vain				*	
Thelotremataceae	*Diploschistes hensseniae* Lumbsch & Elix		*	*		
Thelotremataceae	*Diploschistes ocellatus* (Vill.) Norman		*	*	*	
Thelotremataceae	*Diploschistes thunbergianus* Lumbsch & Vezda				*	
Verrucariaceae	*Endocarpon aridum* P.M. McCarthy		*	*		*
Verrucariaceae	*Endocarpon simplicatum* (Nyl.) Nyl. var. *simplicatum*				*	

#AW: Avon Wheatbelt IBRA Biogeographical Region; **COOL:** Coolgardie IBRA Biogeographical Region

Appendix 3. The fungi recorded at Baladjie Lakes Nature Reserve and Baladjie Rock, April 2009.

Family	Species	Habitat	Substrate
Coriolaceae	*Gloeophyllum* sp.	Eucalypt woodland	On dead decorticated wood
Coriolaceae	*Pycnoporus coccineus* (Fr.) Bondartsev & Singer	On dead shrubs	*Calycopeplus paucifolius* trunk
Geastraceae	*Geastrum ambiguum* Mont.	Eucalypt/ Acacia woodland	In leaf litter
Geastraceae	*Geastrum austral* Berk.	Eucalypt/ Acacia woodland	In leaf litter and soil
Geastraceae	*Geastrum floriforme* Vittad.	Eucalypt/ Acacia woodland	In soil
Podaxaceae	*Podaxis pistillaris* (L.) Fr.	*Acacia burkittii* shrubland	In soil
Sclerodermataceae	*Pisolithus* sp.	*Eucalyptus petraea* woodland	In soil
Tulostomataceae	*Tulostoma operculatum* Long & S. Ahmad	Eucalypt/ Acacia woodland	In soil
Tulostomataceae	*Tulostoma pulchellum* Sacc.	Eucalypt/ Acacia woodland and *Acacia burkittii* shrubland	In soil
Tulostomataceae	*Tulostoma pygmaeum* Lloyd	Eucalypt/ Acacia woodland	In soil
Tulostomataceae	*Tulostoma reticulatum* G. Cunn.		

Appendix 4. The Myxomycetes recorded in moist chambers from bark collected at Baladjie Lakes Nature Reserve and Baladjie Rock, April 2009 WANATS survey.

Family	Species	Substrate
Arcyriaceae	*Arcyria pausiaca* H.W.Keller & Bub.-Zurey	*Eucalyptus petraea* bark
Arcyriaceae	*Arcyria pomiformis* (Leers) Rostaf.	*Eucalyptus petraea* bark
Stemonitidaceae	*Colloderma oculatum* (C.Lippert) G.Lister	*Acacia burkittii* bark
Physaraceae	*Physarum viride* (Bull.) Pers.	*Eucalyptus petraea* bark
Stemonitidaceae	*Stemonitopsis dictyospora* (Celak) Nann.-Brem.	*Eucalyptus petraea* bark
Trichiaceae	*Trichia contorta* (Ditmar) Rostaf.	*Acacia burkittii* bark

Appendix 5. Birds recorded at Baladjie Rock, Baladjie Lakes Nature Reserve and adjacent to flora quadrats (April, 2009).

Species	BR1	BR2	BR3	Opportunistic records
Australian Owlet-nightjar				*
Australian Raven				*
Australian Ringneck	*	*		
Banded Lapwing				
Black-faced Cuckoo-shrike	*			
Brown Falcon				*
Brown Honeyeater				*
Chestnut-rumped Thornbill				*
Crested Bellbird				*
Galah				*
Grey Shrike-thrush				*
Inland Thornbill				*
Nankeen Kestrel				*
Purple-crowned Lorikeet			*	
Red-capped Robin	*			
Red-tailed Black-Cockatoo				*
Singing Honeyeater	*	*		
Spiny-cheeked Honeyeater		*	*	
Striated Pardalote				*
Wedge-tailed eagle	*			
Weebill				*
White-eared Honeyeater				*
White-winged Triller				*
Willie Wagtail				*
Yellow-plumed Honeyeater			*	

OBITUARY

GRAEME EDWARD RUNDLE AM

BORN: 7 FEBRUARY 1944
DIED: 8 DECEMBER 2012

Graeme Rundle was a lifelong conservationist and tireless advocate for the State's National Parks and conservation reserves. The high esteem in which Graeme was held was recognized in the 2013 Queen's Birthday Honours List when he was posthumously awarded a MEMBER (AM) IN THE GENERAL DIVISION "for significant service to conservation and the environment in Western Australia".

Graeme's focus and commitment to the environment was evident from his schooldays. I first knew Graeme from our time together at Governor Stirling Senior High School. For one of our term projects in Geography we were required to produce an assignment on an area of interest covering features such as climate, geology, landforms and human use. I cannot remember what subject I chose but I do remember with great envy the amazing dossier produced by Graeme. He had compiled an extraordinary amount of information together with maps and colourful drawings of the then almost unknown Hamersley Ranges in the remote Pilbara Region. His essay ended with a very insightful justification of why the area should be a National Park. As outlined in John Bailey's personal tribute, Graeme was later pivotal in the establishment of what is now known as Karajini National Park.

Throughout his life Graeme worked tirelessly to achieve his core objectives, often taking on the most arduous roles to achieve lasting outcomes. Significant roles undertaken by Graeme included:

- a range of executive roles from 1968 until 2012 including Treasurer and Secretary with the Conservation Council of Western Australia
- he was the driving force in establishing the Western Australian National Parks and Reserves Association in 1978 and subsequently held a number of executive roles including President, Secretary, newsletter Editor, and Delegate to the Conservation Council, 1978–1990
- Community Member, Conservation Commission of Western Australia, from 1990 to 2012
- Member, Management Board, Port Kennedy Management Board, for 10 years
- Founding member of the Darling Range Forum, which

successfully campaigned for the creation of a Darling Range National Park – 1980s

- Community Member, Chamber of Minerals and Energy of Western Australia, for many years
- Represented the Conservation Council of WA on various boards and committees run by CALM/EPA, including: Member, Pastoral Lands Board, for 7 years
- Member, Dieback Consultative Council, Parliament of Western Australia, 1997
- Member, Environment Advisory Group, Perth Airport, for many years
- Member, Golden Gecko Assessment Panel and Selection Committee, Western Australian Department of Mines and Petroleum, for many years
- Involved in establishing the Roadside Conservation Committee, 1980
- Executive Officer, Conservation through Reserves Committee, Environmental Protection Authority, 1972–1974 and member of the System 6 Tourism Subcommittee 1976
- Hon. Secretary, Western Australian Naturalists' Club 1980
- Council Member Western Australian Naturalists' Club 1981–1982.

I was privileged to have known Graeme for most of his life and remember with great fondness participating with him on a number of camping trips with the Naturalists' Club. In addition to sharing the highlights of the day, future dreams were discussed well into the night round the campfire.

JOHN DELL

GRAEME RUNDLE: A PERSONAL TRIBUTE

BY JOHN BAILEY

I first met Graeme Rundle in 1983 around about the time that the Gordon below Franklin Dam was stopped by the Commonwealth Government. That momentous decision led me into a term as the President of the Conservation Council through which I met Graeme as the Council member from the WA National Parks Association. Most of the time though Graeme talked about roadside vegetation and I soon learnt that he was a terrier when it came to our road verges. It seemed there was nothing that he didn't know about roadsides, including the origin of the length measure of a chain.

As I built up my knowledge about WA conservation issues I soon came upon the Conservation through Reserves Committee process and the Red Books, starting with System 6 and moving outwards. And then lo and behold Graeme popped up as having been intimately involved in this grand scheme to provide the expanse of WA with a reserve system of which we could be proud. We haven't got all the way of course, but Graeme played a key role in nudging the State forward. Once again that terrier was evident.

In the mid-1980s a proposal for an alluvial gold mine appeared for the Southern part of what was then the Hamersley Range National Park required Council attention. Who better to help than Graeme. It was then that I heard about his shoeboxes stuffed full of documents in the shed – samples arrived in Wellington St where the Council was located back then. Graeme's fondness for multiple fonts, and multiple colours when that became possible, was revealed amongst these papers. From memory that gold mine did not go ahead – we were not so lucky with iron ore in and around the park.

Many years later, and only a few years ago now, Graeme's lifetime of effort for conservation was recognised by the award of a medal by the Conservation Council, the Bessie Rischbeith Conservation Award for significant voluntary service in 2006. In the citation it was revealed to me – many others present would have already know this I'm sure – that Graeme was pivotal in the creation of the now Karajini National Park.

I have visited Karajini too few times, but we should all thank Graeme for his vision in extending the conservation estate beyond the South-West and beyond the gorges. I will always think of Graeme when I visit Karajini. So to you Graeme – thank you for all that you did for nature conservation in our wondrous Western Australia.

CLUB NEWS

Programme

General Meetings and Branch Meetings are held at various venues in Nedlands, Kalamunda, Rockingham and North Beach.
The Retired and Leisured Group meets on alternate Wednesdays at 10a.m.
Excursions and field days are planned from time to time and will be advertised in the Club's monthly newsletter "The Naturalist News".

THE WESTERN AUSTRALIAN NATURALIST
(Journal of the W.A. Naturalists' Club)

Editor
MR JOHN DELL

The Western Australian Naturalist publishes original data on all branches of natural science pertaining to Western Australia. Originals and two copies of manuscripts should be submitted to the Editor for review by two referees. Authors are requested to follow current editorial style. If possible, manuscripts should be submitted in Word format. High quality illustrations suitable for some reductions in size are preferred.

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Members are reminded that they may make financial contributions to the club. This funding is very important from the Club's point of view, as it helps our publication activities, field station maintenance and other miscellaneous activities. Members are asked to remember the club and its needs when preparing their Wills and Testaments.
The WA Naturalists' Fund is entered in the register of Environmental Organisations. Donations of $2.00 and over are tax deductible under item 1 Section 30-15 and Subsection 30B of the Income Tax Assessment Act 1997.

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Typeset and printed in Western Australia